Developing clinical reasoning in medical students: a realist review and evaluation

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Acknowledgements

As I'm sure many a PhD student would affirm, my PhD journey has been a test of perseverance in the face of many challenges. To that end, there are many people, without whom my PhD would not have been possible and deserve special thanks.

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Abstract

Background

Clinical reasoning (CR) is a complex process which doctors utilise to diagnose and manage patients' problems. CR comprises both intuitive, non-analytical reasoning (NAR) and deliberate, analytical reasoning (AR) interacting with contextual factors. CR development occurs through acquisition of knowledge and experience and consequent development of mental models of disease called illness scripts. Accurate CR is important to provide patients with accurate diagnoses and effective management plans for their problem. Therefore, developing the foundations of CR in medical students is an important aspect of their education. Education to develop CR in the real world is highly complex, with multiple factors or contexts impacting outcome. How educational interventions interact with context to develop CR in medical students as an outcome is understudied. This research aims to examine the ways in which educational interventions develop CR, how, in which circumstances and for which groups they are more likely to be effective.

Methodology and methods

This research comprises a realist review of the literature and a realist evaluation of CR development in medical students at the University of Nottingham Medical School. A realist methodological approach to research considers the contexts that impact interventions and considers the ways in which interventions produce their results by analysis of interactions between context, mechanism and outcome. Initial programme theory was developed and refined iteratively through a realist review including twenty-eight primary studies. This resulted in a refined programme theory which was further tested and refined using individual and group interviews. The thirty-one participants comprised of medical students, clinical teachers and faculty members. Data

were analysed using a realist logic including abductive and retroductive inference to create context mechanism outcome configurations (CMOCs). The output of the research is a refined programme theory which was utilised to suggest recommendations for educational practice and policy.

Results

Educational interventions, including but not limited to simulation, interacting with patients and discussion with clinical teachers, provide five key resources to students. These include learning about the CR process, participation in CR tasks, learning from mistakes, encouragement of NAR or AR and integration of strategies that promote effective long-term acquisition of knowledge.

These educational resources are affected by students' clinical domain knowledge, self-confidence, clinical experience and goal orientation or mindset; by teachers' motivation, confidence and rapport or relationship with students; and by the wider organisational factors such as available time, space and resources, perception of assessment practices and curricula prioritisation. The student, teacher and wider organisational contexts impact both how the educational interventions develop CR in individuals and impact opportunities for CR development.

Discussion and conclusions

This research has determined how, why and in what circumstances CR develops in medical students. The resultant programme theory has enabled a deeper and holistic understanding of CR development in the real world and subsequent recommendations for how this might be improved. To promote the most effective CR development, education should be individualised to students' clinical domain knowledge, self-confidence, experience and motivation. Teachers will be better able to assess individual students'

characteristics when curricula promote continuity of education through building of positive student-teacher relationships. Building confidence in clinical environments through early years experiences or promotion of interventions such as students working as health care assistants (HCAs) will aid engagement and learning the clinical environments. Students should be taught how to learn effectively through integration of learning strategies to aid long term knowledge retention and through reinforcement of a growth mindset to aid development of mastery goal orientation. Additionally, engagement in the clinical environment is more likely when assessments are aligned with real, uncertain clinical practice which increases opportunities for CR development.

Thesis structure

Chapters 1 and 2 introduce the key background literature pertinent to the research. Firstly, introducing the topic of CR and its conceptualisation as a process and skill, incorporating analytical and non-analytical cognitive processes. The importance of CR for healthcare professionals in ensuring effective and safe patient care is outlined. CR development commences at medical school in students and the educational approaches to aid development are discussed. This research aims to understand the contexts that affect the education and development of CR in medical students in the real world. This aim dictates that a research approach designed to understand complexity is required and realist research is introduced.

Chapter 3 orientates the reader to the philosophical perspective of scientific realism with a brief overview of its development and key philosophical assumptions. The terminology used in realist research is described to allow the reader to understand the specific use of terms in the research including context, mechanism and outcome descriptions. Following this, an explanation of how a realist approach was applied to this research is given together with a brief overview of realist synthesis and evaluation and their use in research.

Chapter 4 outlines the first component of the research to answer the research question by way of a systematic overview of the existing literature interpreted through a realist lens, a realist review. The methods of literature searching and the iterative nature of theory development are described followed by a transparent account of how the literature contributed to theory development. In this realist review contexts at individual, teacher and wider organisational levels were sought. However, focus on individual student contexts became the eventual focus of the review.

Results of the realist review are presented in chapter 5, highlighting the individual student contexts that affect educational effectiveness of various educational interventions to develop CR ability as a programme theory. Broadly the findings relate to the students pre-existing knowledge, self-confidence and self-efficacy and when groups of students are taught together with differing knowledge levels. The results are discussed with respect to the existing literature and strengths and limitations of this research method.

Chapter 6 details the methods of the realist evaluation of CR development in medical students at the University of Nottingham. Realism as a methodological approach determines how research data is interpreted, by looking for explanatory relationships between context and outcome by highlighting mechanisms. The main method in this research was multiple semi-structured interviews with students, teaching staff and faculty members. The ways realist views are used to approach the interviews and data analysis are detailed.

The main results of the empirical study and overall key findings of the research are given in chapter 7 with a narrative report of the development of each theory. Results are presented from the resources delivered by educational interventions used to develop CR and the contexts that impact are discussed. There are many educational interventions or activities that develop CR ability by making various resources available to students. These resources are knowledge acquisition and retention, allowing participation in CR tasks, learning from mistakes, encouraging analytical or non-analytical reasoning, and developing understanding of the reasoning process. Each of these resources is discussed in greater detail in this chapter alongside the relevant contexts and impact on CR development as an educational outcome.

Finally, chapter 8 discusses the overall results with respect to other literature. The implications of the work and recommendations for educational practice and policy are considered. There are many educational interventions within medical education, many of which develop students CR ability. Often these approaches take a uniform approach to education but this research highlights how many contexts affect each educational intervention. A one size fits all approach needs to be reconsidered in medical education and steps taken to promote an individualised approach to increase the educational effectiveness. Other changes to practice and educational policy are suggested which may aid CR develop more effectively in medical students. Suggestions for further research are discussed including ensuring context consideration in CR development research and exploring factors that impact CR development further such as the impact of motivation and self-confidence.

Publications, dissemination, and awards

Publications

Richmond, A. *The chicken and the egg: Clinical reasoning and uncertainty tolerance*. Medical Education. 2022; 56(7): 696- 698. doi:10.1111/medu.14814

Richmond A, Cooper N, Gay S, Atiomo W, Patel R. *The student is key: A realist review of educational interventions to develop analytical and non-analytical clinical reasoning ability*. Medical Education. 2020;54(8):709-19.

Richmond A, Cranfield T & Cooper N. *Study tips for medical students*. BMJ, 2019; 365; k663

Richmond A, Atiomo W, Cooper N, Gay S, Patel R. *A realist synthesis of educational interventions that are used to develop clinical reasoning with respect to dual information processing in undergraduate students*. PROSPERO 2017. CRD42017072029. Available from:

https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42017072029

Dissemination

2019 Small Grants award winner: Educational interventions to develop analytical and non-analytical clinical reasoning in medical students: A realist review and evaluation. Presentation. ASME annual scientific meeting 2021. July 2021

The Student is Key to Success: Educational interventions to develop analytical and non-analytical clinical reasoning: a realist review. Presentation. Undergraduate Medical Education Conference, Nottingham University Hospitals NHS Trust. June 2019

Developing 'fast' and 'slow' thinking ability in doctors in training when diagnosing and managing patients' problems. RME (Researching Medical Education) National conference. Masterclass presentation: Presenting research in plain English. ASME (Association for the Study of Medical Education). November 2018.

Teaching techniques to promote more effective learning. Presentation. Undergraduate Medical Education Conference, Nottingham University Hospitals NHS Trust. June 2018

The Science of Successful Learning. Presentation. Royal Derby Hospitals NHS Trust Teaching and Learning conference. May 2018

Educational interventions that develop dual information processing with respect to clinical reasoning in medical undergraduates: a realist perspective. Poster and presentation. University of Nottingham Post graduate research impact forum. 2017.

Impact

Richmond A, Cooper N, Gay S, Atiomo W, Patel R. *The student is key: A realist review of educational interventions to develop analytical and non-analytical clinical reasoning ability*. Medical Education. 2020;54(8):709-19 was the subject of a commentary in the journal:

> Ribeiro, L. M. C., & Moura, A. S*. 'Hands-on' ideas to provide student-targeted clinical reasoning educational interventions.* Medical Education. 2020*;354*(8), 680-682.

Awards

Recipient of ASME (Association for the Study of Medical Education) small research grants 2019 for the work - *In what ways do educational interventions develop analytical and non-analytical clinical reasoning ability in medical students. The abstract of the presentation of this award can be found at:*

> Abstracts for ASME Annual Scholarship Meeting 2021 – Disrupted Medical Education. *Awards Abstracts. Clin Teach. 2021;18(S1):p24*

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Abbreviations

ASME: Association for the Study of Medical Education

AOME: Academy of Medical Educators

AR: Analytical Reasoning

C: Context

CBD: Case Based Discussion

CFT: Cognitive Flexibility Theory

CLT: Cognitive Load Theory

CTF: Clinical Teaching Fellow

CMOC: Context, Mechanism, Outcome Configuration

CR: Clinical Reasoning

DIP: Dual Information Processing

ECE: Early Clinical Experience

GEM: Graduate Entry Medicine

GMC: General Medical Council

GP: General practice or practitioner

HCA: Health Care Assistant

I(R)PT: Initial (Rough) programme theory

LIC: Longitudinal Integrated clerkship

LEP: Local Education Provider

Mini-CEX: Mini Clinical Evaluation Exercise

Mresource: Mechanism resource

Mresponse: Mechanism response

NAR: Non-Analytical Reasoning

NHS: National Health Service

O: Outcome

PBL: Problem-Based Learning

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PG(ME): Postgraduate (Medical Education)

RAMESES: Realist And Meta-narrative Evidence Syntheses: Evolving Standards

RR: Realist review

RE: Realist evaluation

SCT: Script Concordance Test

SDT: Self-determination Theory

SRL: Self-Regulated Learning (theory)

SRL-MAT: Self-Regulated learning – Micro analytic Assessment and Training

UG(ME): Undergraduate (Medical Education)

Chapter 1: Clinical reasoning

Clinical reasoning: Conceptual clarity or confusion?

Clinical reasoning (CR) has been described as a God term (Gruppen, 2017); a term or concept used and accepted so widely that it supersedes any other potential terms used to describe the construct, examples including truth, freedom or justice. With respect to God terms, Lingard (2009) notes as she writes about competence that, using a term so widely and surely, the exact meaning and nuances of the concept may be lost. CR is a term that fits this definition; potent, pervasive, widely used and positively evaluated but on further examination, it is surprisingly vague.

CR is used across healthcare professionals and, when focussed on medicine, CR has been described as the core and "defining characteristic of the profession" (Durning et al., 2013, Gruppen, 2017, Young et al., 2020). Whilst this highlights that CR is a vital skill, definitions of what exactly CR is have varied across the literature. Over 100 different terms referring to the concept of CR have been found in the literature (Young et al., 2018, Young et al., 2020). Additionally, some studies use the term CR interchangeably with other terms, suggesting that these authors consider them synonymous. Such terms used in a recent paper discussing the benefit of deliberate reflection and CR included diagnostic reasoning, clinical decision making, clinical problem solving, problem solving and clinical reasoning (Mamede and Schmidt, 2022). Finally, many components of clinical practice appear to be related to the process of CR, the risk being that *all* aspects of clinical practice are associated with CR. This dilutes CR as an important concept to be developed and as Gruppen (2017) notes, "*if the term [CR] comes to encompass any physician thinking about clinical problems, the concept becomes so expansive as to risk becoming useless*". The

lack of conceptual clarity presents challenges for those seeking to understand CR as a concept, those wishing to develop CR in themselves or others and for those who wish to deepen understanding of CR through research (Gruppen, 2017). Furthermore, Durning et al (2013) suggest that a lack of clear definition effectively undermines the practice of teaching, developing and assessing CR. Despite the challenges, providing a definition of CR is important for both research and teaching and CR development. Consequently, an overview of the CR literature and rationale for the conceptualisation of CR utilised in this research follows.

Over the last fifty years, research into CR has increased significantly with rapidly growing interest in CR over the last twenty years with the advancement of patient safety agendas and the search for ways in which to improve diagnosis and reduce diagnostic error in healthcare (Kohn et al., 1999, Balogh et al., 2015). As a result of this the CR literature often focusses on diagnostic reasoning and diagnosis as the outcome of CR (Ilgen et al., 2016). This is firstly because diagnosis is often viewed as the key component to get right in order to avoid an error and secondly, in research regarding why errors are made or in trying to reduce diagnostic error rates, correct or incorrect diagnoses are a relatively easy measure (McBee et al., 2017). Some have argued that diagnosis however is only a component of the CR process (Ilgen et al., 2016), where the management of the patient plays a more vital role in understanding why errors occur, so called 'management reasoning' (Cook et al., 2019). Whereas diagnosis often represents a binary correct or incorrect, management of a patient problem is more complex. Multiple factors pertaining to the patient and their choices, clinician experience and preferences and various logistical factors including treatment availability, all impact management decisions (Cook et al., 2019). In addition, patient treatment and management are often required when the diagnosis is unclear or uncertain, meaning that focus on diagnosis alone is insufficient for the full understanding of the CR process. This suggests that diagnosis and management are components of CR overall, but neither

term is synonymous with CR individually. Furthermore, CR may be considered to comprise of additional components which have been described by Daniel et al (2019) as part of their scoping review into CR assessment methods as shown in Table 1. Determining the components considered part of CR (Cooper et al., 2021) aids with understanding, which will aid acceptance of a CR definition.

COMPONENT	DEFINITION
Information gathering	Acquiring the data to generate or refine diagnostic hypotheses. This may include history taking, physical examination, investigations, review of the medical notes or through observation of the patient. Selection of information to gather is driven by knowledge representations and illness scripts.
Hypothesis generation	An early non analytical or analytical processing of potential diagnoses that explain the patient's problem. The interaction of illness scripts and the information gathered continuously refine the potential hypotheses.
Problem representation	A dynamic representation of the salient features of the case that can be communicated as a summary using semantic qualifiers.
Differential diagnosis	A list of most likely diagnoses given the representation of the problem. As the strength of confidence and evidence from information gathering increase, a leading diagnosis emerges.
Leading or working diagnosis	A diagnosis for which the doctor's threshold of likelihood has been crossed to justify additional investigations or treatment, even if the diagnosis is not certain.
Diagnostic justification	The attempt to use the evidence to defend one or more diagnoses as being most likely, whilst comparing other potential diagnoses. There may be a written or verbal requirement to explain one's justification.
Management and treatment	The actions that result from the previous components including prognostication, management, treatment and justification for one's actions. This may also include a watch and wait approach.

Table 1: Components of the clinical reasoning process adapted from Daniel et al (2019)

Overall, it is acknowledged that CR is a complex and multi-faceted skill (Gruppen, 2017, Croskerry, 2018) which encompasses multiple components (Daniel M et al., 2019, Jackson et al., 2022). In order to understand the theoretical assumptions and improve understanding further, Koufidis et al (2021) reviewed how CR has been conceptualised in the literature. They found that CR could be conceptualised as a cognitive activity, a contextually situated activity or a socially mediated activity. CR has been mainly conceptualised as a cognitive or contextually situated activity and the authors state "it holds the view that both cognition and context are inseparable and should, therefore, be studied together" (Koufidis et al., 2021). Whilst the components of CR as described by Daniel et al (2019) are useful, alone these do not acknowledge and clarify the role of context in CR.

Traditional views of context pertain only to the clinical context which broadly relates to the setting of the clinical encounter or the clinical content (Durning et al., 2010). However, context is more complex and encompasses multiple independent and inter-dependant factors. Durning and Artino (2011) describe factors related to the individual clinician, including knowledge and experience, the patient, including language and familiarity with the physician and the encounter, including appointment length and location, that interact and affect the clinical outcome. Croskerry (2018) highlighted six "clusters" of factors that impact CR. Physician factors are divided further into demographic, cognitive or thinking styles and homeostatic or circadian factors such as sleep deprivation and stress. Additional clusters include those pertaining to the system, the clinical problem itself and those related to the patient including family and caregivers. These perspectives (Durning and Artino, 2011, Croskerry, 2018) serve to illuminate the vast interconnectivity of factors that impact the CR process.

Despite the recognition of the importance that context plays in CR; context has been described as being overlooked or reduced to individual elements in the CR literature and research (Koufidis et al., 2020). This approach to CR research is highlighted by the majority of CR research performed in laboratory conditions where confounding variables are stripped away to study the item of interest (Croskerry, 2020b) and little studied 'in vivo' where the processes actually take place. Gruppen and Frohna (2002) described this approach to CR research some 20 years ago, as occurring "within a vacuum"; devoid of context resulting in an incomplete understanding of the CR process. Whilst experimental studies have a role to play in developing understanding, in order to progress understanding of CR, and therefore its teaching and development, there is still a call to research CR in the 'natural' or clinical environment (Gruppen and Frohna, 2002, Torre et al., 2020); that is to research CR within context (Bleakley, 2021). The drive to understand CR deeply highlights how important CR is within healthcare.

Whilst CR has been described as a core component of medical practice (Gruppen, 2017), as highlighted, the definition of CR is debated. Young et al (2018) attempted to define what was, and what was not, considered to be under the umbrella of CR. They found wide differences in opinion within their research team, with some defining CR only when it occurs within the mind of the healthcare provider, some acknowledging the role of interaction between the healthcare provider and patient or other sources of information (such as expert opinion or investigation results) and some believing that anything that contributed to the outcome of diagnosis or management was accepted as being included in the definition of CR. Daniel et al have defined CR as "*a skill, process, or outcome wherein clinicians observe, collect, and interpret data to diagnose and treat patients. Clinical reasoning entails both conscious and unconscious cognitive operations interacting with contextual factors"* (Daniel M et al., 2019). The same operational definition was adopted by a UK consensus statement on how to best develop CR in undergraduate curricula (Cooper et al., 2021).

Examining the definition by Daniel et al (2019) further, CR could be viewed as a *process* when it is regarded as occurring within the mind of the individual, and it is acknowledged that additional sources of information or others will contribute to this cognitive process. CR could also be a *skill* which is generally defined as an ability to do an activity or job well. CR is described as an *outcome* when an output such as diagnostic accuracy is used as a marker of CR. It is the view of this researcher that CR itself is not an outcome, but CR is a skill or process that underpins observed outcomes; that is decisions about diagnosis, management and patient care. Further discussion about the definitions of outcome in this research can be found in Chapter 3.

Given that CR is viewed by this research primarily as a cognitive process affected by various contextual factors, attention is now paid to the detail of the cognitive processes involved in CR.

Clinical reasoning as a cognitive process

Interest in how doctors make clinical decisions accelerated in the 1970's (Monteiro. S et al., 2020). At this time, the hypothetico-deductive model of CR was proposed (Elstein et al., 1978) whereby clinicians would test a series of potential diagnostic hypotheses through various methods, ruling them in or out deductively based on the information gathered (Schwartz and Elstein, 2008). This approach to CR was criticised as in experts the CR process doesn't always follow the same pattern as novices (Groen and Patel, 1985) and in experts, the CR process is seemingly automatic and does not require further deliberation over potential causes of the patients problem.

Dual information processing (DIP) theory (Evans, 2008) provides a theoretical basis for explanation of the criticisms and has been described by multiple authors (Evans, 2008, Croskerry, 2009b, Kahneman, 2011, Evans and Stanovich, 2013). The guiding principle of DIP theory is that human reasoning takes one of two routes; non-analytical or type 1, or analytical or type 2 (Evans and Stanovich, 2013). Type 1 processes include pattern recognition and intuition, they are autonomous and do not require working memory. Type 1 processes are also described as non-analytical reasoning (NAR) within this research. Type 2 processes are also known as reflective reasoning and are associated with deep cognition and requirement of working memory. Type 2 processes are also described as analytical reasoning (AR) within this research. Table 2 highlights these key defining features.

Type 1 processes (NAR)	**Type 2 processes (AR)**
Does not require working memory	*Requires working memory*
Autonomous	*Cognitive decoupling; mental simulation*

Table 2: The defining features of Type 1 and Type 2 reasoning processes (Evans and Stanovich, 2013)

DIP theory is further subdivided into 2 main forms; the default-interventionalist and the parallel competitive (Evans and Stanovich, 2013). In the former, type 1 processes take precedent; the default setting, but when humans lack the experience or knowledge of the problem at hand, type 2 or reflective processes intervene. In the latter form of DIP theory, type 1 and 2 processes occur in parallel which may result in cognitive conflict which then requires resolution (Evans, 2007). Given that most of our day-to-day reasoning and decisions defaults to rapid, intuitive processing (type 1) so as not to overload working memory (Norman et al., 2017), human cognitive processing

has been described as a “cognitive miser” (Croskerry, 2009a, Kahneman, 2011). This is the default-interventionalist form of DIP and is supported by evidence from cognitive psychology and neural imaging (Evans and Stanovich, 2013, Durning et al., 2015a). CR, as a human cognitive process, can be theorised to follow this same guiding principle (Croskerry, 2009b) and is proposed as the form of DIP accepted in this research.

Within the clinical encounter highlighting the default-interventionalist model of CR, Figure 1 (Croskerry, 2009b) illustrates the cognitive path a clinician may take when arriving at a diagnosis. It is important to appreciate that the system is in constant flux and change from one system to the other may occur during the clinical encounter if the clinical condition is recognised or not and if additional information fits or not with the clinicians’ knowledge and understanding of the potential diagnoses. This model uses diagnosis as an end point for CR but as previously mentioned, management is also incorporated in reasoning and similar cognitive processes are likely to be associated in this component of CR.

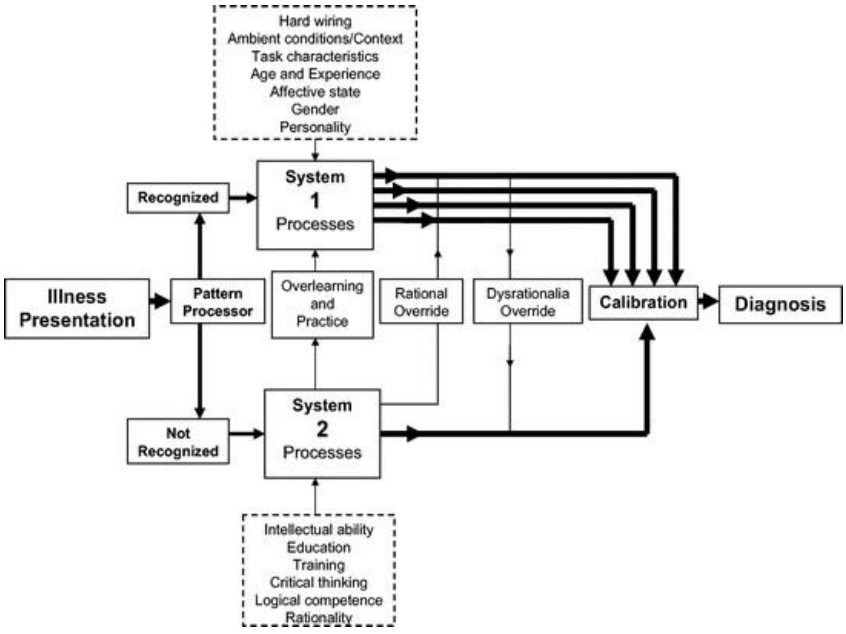

Figure 1: Model for diagnostic reasoning based on pattern recognition and dual-process theory. (Croskerry, 2009b)

With respect to type 1 reasoning, firstly, Evans and Stanovich (2013) propose that type 1 reasoning processes include those that have been "practiced to the point of automaticity" highlighting the role of learning and knowledge acquisition to development of type 1 processes. Secondly, studies of experts in medicine with many years of accumulated experience (Ericsson, 2004), reinforce that a cardinal feature of expertise is highly accurate NAR (Norman et al., 2017, Monteiro et al., 2018). Evidence from neural imaging corroborates that experts use more NAR than students (Durning et al., 2015a). Finally, evidence suggests that CR is both case and content specific, that is, expertise in one clinical area is not transferable to others (Monteiro. S et al., 2020). Taking all 3 points together, they highlight the vital role of knowledge in CR, in the development of accurate type 1 and type 2 processes. In fact knowledge has been described as the "most important component of the clinical reasoning process" (Gruppen and Frohna, 2002). To illuminate the value and importance of knowledge to CR further, reorganization of knowledge has been shown to have benefit to reducing diagnostic error (Norman et al., 2017), one outcome of the process of CR, whereas interventions targeting thinking processes more generally do not have any effect. When viewing CR through the lens of knowledge and content specificity (Monteiro. S et al., 2020), this is not at all surprising since training oneself to think in a different way or differently about a clinical problem will have no effect if one has no knowledge of the clinical problem at hand (Dhaliwal, 2016). Some authors have however disputed that knowledge is the most important element of CR given that the research from diagnostic error suggests most clinical errors occur when the clinician had knowledge of the condition (Graber et al., 2005b) or errors occur when the condition is very common. These findings prompted interest into the role of cognitive biases in CR as a cause of error.

Cognitive biases

Type 1 reasoning leads to correct diagnoses most of the time but some authors hold that failure in Type 1 thinking leads to diagnostic error and ultimately harm to the patient (Berner and Graber, 2008). This is based upon the view that type 1 reasoning is prone to cognitive biases. Cognitive bias is a negative term applied when a mental shortcut or heuristic has failed to provide the correct response and potentially caused harm to the patient (Balogh et al., 2015). When understanding the DIP model of reasoning in this way, intuitive thought is a source of error and to rectify this, one must simply slow down and think analytically. An approach to teaching that has been offered to allay the effects of biases are cognitive forcing strategies (Croskerry, 2003) which make students and doctors aware of potential biases and employ metacognitive techniques, such as analytical reasoning, to overcome them. However, evidence for this assertion is lacking (Evans and Stanovich, 2013, Sherbino et al., 2014, Norman et al., 2017), reinforcing that cognitive biases, as a component of type 1, subconscious reasoning, are not readily available for adaptation in order to improve CR outcome.

Also in disagreement with the potential negative effect of cognitive biases on CR, is the fact that the application of this term is a retrospective one; in the moment, the clinician doesn't 'know' they are applying a cognitive bias as by the very nature, they are subconscious mental shortcuts (Zwaan et al., 2017). In addition, it is not possible to know exactly what was the cognitive error that led to the misjudgement and studies have shown that even experts disagree on which cognitive biases may have been at fault, and there is overlap between them (Zwaan et al., 2017). Furthermore, applying a conscious check over your decisions is not always possible or practical and so hasn't been shown to give benefit, especially in experts where their T1 reasoning processes are used for the majority of decision-making (Smith and Slack, 2015, Brush et al.,

2017). Most of the time, these 'cognitive biases' are effective mental shortcuts applied as intuition or pattern recognition that, most of the time, lead to excellent, timely and effective patient care (Brush et al., 2017). This view suggests to reduce error, it is not through cognitive forcing strategies or even awareness of biases (Sherbino et al., 2014) but through better mental representations of disease knowledge, such that when our brains do take a mental shortcut, it is more likely to be a decision without error (Norman et al., 2017). Our brains are designed in such a way that they want to take shortcuts (Croskerry, 2009b), making sure they have the knowledge and accumulated experience to not make an erroneous short cut is the most important thing and this can be achieved through education (Brush et al., 2017).

Norman and Eva (2010) reinforce the beneficial effect of type 1 reasoning, finding that by forcing expert clinicians to use type 2 reasoning when solving clinical problems, error is more likely (Norman and Eva, 2010). In agreement, Monteiro et al (2015) studied the effect of type 2 thinking, by encouraging reflection on diagnoses, on overall accuracy. They found that reflection did not improve accuracy and altered diagnoses were more likely to be incorrect. In teaching techniques, Sherbino (2014) concluded from a controlled trial that, with novices at least, teaching cognitive forcing strategies to overcome 2 main cognitive biases (availability and search satisficing biases) are not effective in reducing diagnostic error. Further in support that diagnostic errors do not always arise from the fast, intuitive nature of type 1 reasoning, Sherbino and colleagues (2012) found that response time is lower in cases where clinicians have higher diagnostic accuracy.

When the evidence against being able to 'train out' cognitive biases is examined through the lens of knowledge structure being the key element to develop DIP CR, we see that cognitive biases are a feature of type 1 reasoning but the term bias, as a negative, is not always a fault in our reasoning. Indeed,

it is widely accepted that type 1 reasoning most frequently produces correct and rational answers. The view taken by the research presented in this thesis, is that the evidence pertaining to cognitive biases that suggest humans can train away their natural type 1 cognitive processes is a fallacy (Evans and Stanovich, 2013). These processes have been shown to be a normal part of human reasoning (Dhaliwal, 2016). Acceptance of this and recognition that the way that knowledge is stored in conjunction with wider contextual factors impacting CR, is key to CR development.

Knowledge structure and organisation: script theory

Knowledge has been emphasized as the most important aspect of CR to ensure accurate reasoning processes. Krathwohl (2002) extends knowledge from purely being factual, to also include conceptual, procedural and metacognitive. This conceptualisation of the term knowledge highlights that to effectively reason through a problem, factual knowledge is required but it is also necessary to know the connections with other similar information, know how to apply it to a clinical situation, have ability to know how to get the necessary knowledge from the situation and understand self-limits on this knowledge application. Some studies investigating the reason for diagnostic error have assumed knowledge could not be at fault as error occurred in common conditions whereby the clinicians had the factual knowledge required to make the diagnosis but failed (Graber, 2013, Graber et al., 2005a), which as noted promoted interest in cognitive biases. However, this may not take into consideration the other forms of knowledge as described by Krathwohl (2002). Additionally, the structure of knowledge in memory is fundamental for safe and effective reasoning. For this reason, consideration the role of memory in CR is required.

At first, basic biomedical knowledge is acquired and rapidly develops into understanding regarding physiological and pathological disease states (Schmidt HG, 2007). At this novice stage, students will acquire and consider many aspects of the clinical case during CR and use primarily type 2 reasoning. With increasing experience of various case presentations, the clinical knowledge is encapsulated into cognitive representations of disease known as illness scripts (Schmidt HG, 2007, Brush et al., 2022). Encapsulation has been described as "the subsuming or 'packaging' of lower-level, detailed concepts, and their inter-relations, under a smaller number of higher-level concepts with the same explanatory power" (Schmidt HG, 2007). This process is akin to 'chunking' of information as described in cognitive psychology and enables large amounts of information to be stored in smaller 'packets' with lesser demand on cognitive capacity (Gruppen and Frohna, 2002). In addition, illness scripts have been described as having 3 components of knowledge; the enabling conditions (the patient and contextual background the influence the chance of someone having a disease), the underlying pathological processes and the potential consequences (the signs and symptoms that the underlying pathological problem gives rise to) (Custers, 2015a). In the early phases of illness script development, novices focus more on the underlying pathology rather than the enabling conditions. For example, novices would base a diagnosis on the presentation alone without considering that a diagnosis is unlikely given the patients age, sex or other contextual factors which are known to be considered more frequently by experienced doctors (Schmidt HG, 2007). Illness scripts enable multiple aspects of a certain disease to be considered at once, not overloading working memory and are felt to be a hallmark of developing expertise in a clinical domain (Schmidt HG, 2007). At an intermediate stage of training illness scripts will be partially developed and based on prototypical presentations of disease. As illness scripts develop type 1 reasoning will be naturally utilised within CR. With repeated exposure to various presentations of disease illness scripts are refined in structure and content (Custers, 2015a).

In addition, as knowledge and experience increase further, large complex networks between different illness scripts form (Gruppen and Frohna, 2002) allowing clinicians to see connections between different conditions. To be useful for CR, both illness scripts and the connections between them rely on effective retrieval from memory. When a problem is recognized potential illness scripts are automatically brought to consciousness, also known as illness script activation. This is type 1 reasoning in action when applied to CR and, as Dhaliwal (2016) highlights, there is no option to consciously recruit either rapid, non-analytical or analytical reasoning to solve the problem. One's brain does this unconsciously, bringing potential diagnoses that fit the pattern automatically into working memory for further attention, refinement, confirmation, or refutation based upon the developing clinical problem. Even if the problem is not recognised automatically, or perhaps the developing clinical problem means that instantly activated scripts do not fit the problem at hand, type 2 reasoning will enable a further search for components of the patient's history and subsequently additional illness scripts will be activated for consideration.

Activation of illness scripts relies on the problem being recognised, either by type 1 or 2 reasoning (Charlin et al., 2007), and it has been suggested that this relies on the patient's problem being accurately represented using appropriate semantic qualifiers or terms (Gruppen and Frohna, 2002, Cooper and Frain, 2016). These terms such as acute or chronic, intermittent or continuous and so on, enable appropriate scripts to be recognised, normally subconsciously (Charlin et al., 2000, Koufidis et al., 2021) and activated, that is brought to conscious attention. Therefore knowledge of medical language also plays an important role in the way knowledge is structured in memory (Bordage, 2007). Some authors have described type 1 reasoning to be "fluent problem representation" (Gruppen and Frohna, 2002), which takes place

automatically in experts. In novices, representation of the problem is likely to be more effortful and requires conscious attention to each of the components of the problem. It has been suggested that inability to activate illness scripts and therefore access knowledge regarding a particular clinical problem may be related to inability to represent the problem accurately using accurate medical language (Audetat et al., 2013), which is more likely in novices (Koufidis et al., 2021). Accurate problem representation through encouraging the use of semantic qualifiers is thought be also important for CR (Cutrer et al., 2013) and aids illness script refinement (Lubarsky et al., 2015) and will be further considered in chapter 2.

Conceptual model of clinical reasoning

It has been justified that CR is a process comprising both NAR and AR, also referred to as dual information processing which is underpinned by structures of knowledge in memory: illness scripts. The process of CR includes 7 components (Daniel M et al., 2019) and occurs within context, which for this research pertain to the student or doctor, the patient and wider factors relevant to the encounter (Durning and Artino, 2011). This conceptual model of CR is shown in Figure 2.

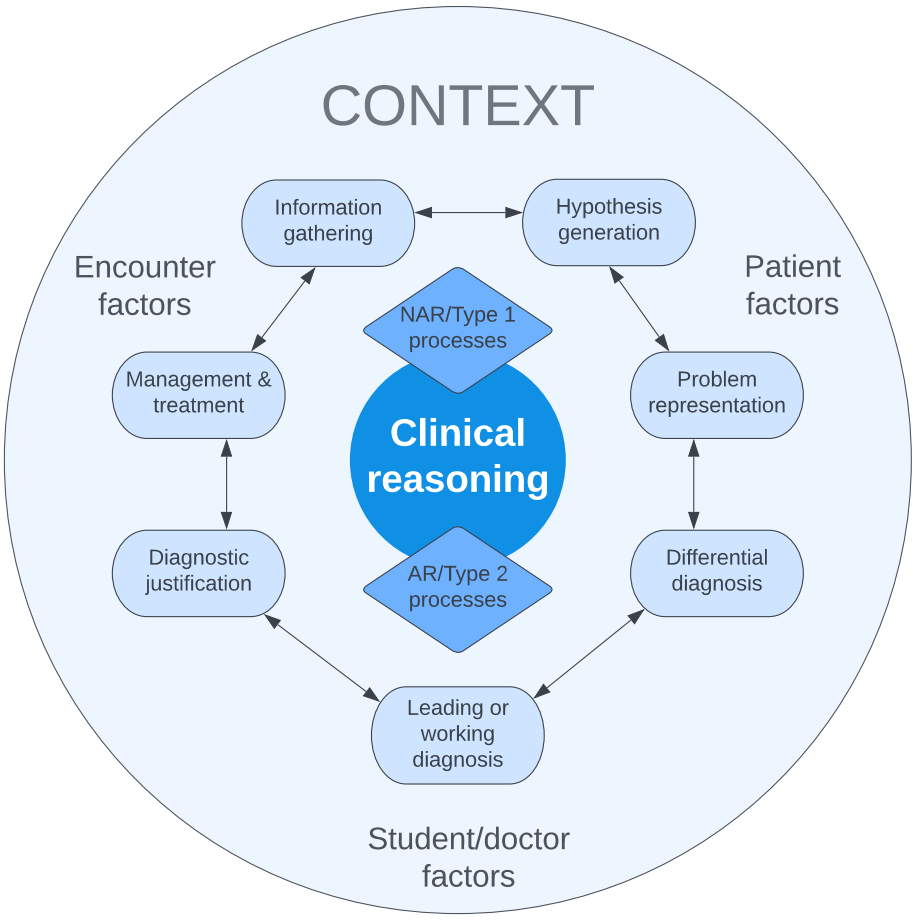

Figure 2: Conceptual model of CR (Evans, 2008, Durning and Artino, 2011, Daniel M et al., 2019)

This conceptual model enables understanding of the educational interventions that would be accepted to be useful in development of CR. Prior to considering how CR is developed, as justification for this research, discussion of why CR is important follows.

The importance of clinical reasoning

The Institute of medicine in 1999 published their report 'To Err is Human: building a safer health system' (Kohn et al., 1999). The report stated that at least 44,000 people in the United States of America alone die each year

in hospitals from preventable medical errors and Elstein (1995) suggests that diagnosis in medicine is wrong 10-15% of the time. The report spurred into action research into driving forward development of safer health systems, with the goal that although human error may occur, systems would be in place to prevent the error reaching the patient and protecting them from harm. Preventable medical errors according to the 1999 report included those related to diagnostic failure, errors in treatment, failure in providing preventative treatment or other errors pertaining to communication or system failures. Much research has focused on making an accurate diagnosis to prevent error (Graber et al., 2005b) but it should be noted that communication of the diagnosis to the patient and their family and commencing an accurate and timely management plan are also key steps (Cooper and Frain, 2016). Similarly, much of the research in this field has focussed so far on individual CR and decision making, but it is not just individual mistakes in CR that leads to error. In healthcare systems, collaborative effort between healthcare providers is the norm (Balogh et al., 2015) and various system factors also affect whether an error reaches, or causes harm to, the patient. However, an individual's CR processes are seen as an element of causation of medical errors and, when considering development of CR processes in medical students, focus is most frequently on the individual student.

In the UK medical system, data from the National Reporting and Learning System (NRLS) as part of NHS England, details numbers of reported medical errors and further subdivides into frequency according to cause and severity. Relevant to this research is the data on errors resulting from "*clinical assessment including diagnosis, tests, scans and assessments*". In the year 2021-2022, there were >114,000 incidents of this type and 893 cases (1%) were graded as severe or having resulted in death of the patient (NHSE, 2022). Graber (2013) attempted to identify the incidence of diagnostic error and found the current literature gives an inaccurate estimation of its true rate. Studies looking at post-mortem diagnosis compared with working diagnosis prior to

patient death give an error rate of 10-20% and studies focusing on specific conditions report diagnostic error ranges from 2% for missed cancers on biopsies up to 51% for sub-arachnoid haemorrhages. Of deaths occurring, clearly not all would be preventable even if the diagnosis had been correct and work by Hogan et al (2012) aimed to estimate the number of deaths which were preventable. Using retrospective case analysis, 5.2% were judged to be preventable which extrapolated to just less than 12000 deaths in UK hospitals being preventable each year.

Medical negligence and malpractice companies list diagnostic error as the leading reason for settled or paid claims (Graber, 2013). A 2017 Medical Protection Society policy paper (MPS, 2017) has highlighted the rising cost of clinical negligence claims to the NHS, with settling of negligence claims in the year 2015/16 reaching £1.5 billion. Steps should be taken to halt the rising costs so that this money can be more effectively spent on NHS services and one potential preventative strategy is education, specifically "…managing individual or system errors that can lead to a claim such as misdiagnosis…"(MPS, 2017). The impact on patient safety and the resultant cost implications serve to highlight the importance of CR to medical practice.

In order to focus on what can be done to improve diagnosis and CR, in 2015 the Institute of Medicine (IOM) published 'Improving diagnosis in healthcare' (Balogh et al., 2015) in response to the lack of attention that diagnosis and diagnostic error had received following the 1999 report (Kohn et al., 1999). Both reduction in diagnostic error and promotion of diagnostic accuracy feature in recommendations throughout the report and of particular interest is the recommendation that healthcare professional education should focus on these areas. In the UK the regulating body of the medical profession, the General Medical Council (GMC), highlights several areas where CR skills are required from medical students graduating from UK medical schools (GMC,

2018), thus recognising the importance of CR in education to the practice of medicine. Although the IOM report (Balogh et al., 2015) focussed specifically on diagnosis, the GMC requirements cover all aspects of the CR process as conceptualised in this research. These include the following:

- Interpret findings from the history, physical examination, and mental-state examination, appreciating the importance of clinical, psychological, spiritual, religious, social, and cultural factors.
- Make an initial assessment of a patient's problems and a differential diagnosis. Understand the processes by which doctors make and test a differential diagnosis.
- Formulate a plan of investigation in partnership with the patient, obtaining informed consent as an essential part of this process.
- Interpret the results of investigations, including growth charts, x-rays, and the results of the diagnostic procedures.
- Synthesise a full assessment of the patient's problems and define the likely diagnosis or diagnoses.
- Make clinical judgements and decisions, based on the available evidence, in conjunction with colleagues and as appropriate for the graduate's level of training and experience. This may include situations of uncertainty.
- Formulate a plan for treatment, management, and discharge, according to established principles and best evidence, in partnership with the patient, their carers, and other health professionals as appropriate. Respond to patients' concerns and preferences, obtain informed consent, and respect the rights of patients to reach decisions with their doctor about their treatment and care and to refuse or limit treatment.

The mandate of the GMC for graduating doctors and the view that CR is a vital skill, makes education and development of CR in medical students an

important concern for medical schools (Cooper et al., 2021). Error in diagnosis and management has clear patient safety and, additionally, significant cost implications for the NHS. Education is one of the essentials to develop and improve CR in doctors of the future (Balogh et al., 2015, Graber et al., 2018). For medical students, developing a foundation of knowledge and skill is important for further CR development in postgraduate education.

Summary of chapter

CR is a process incorporating observation, collection, and interpretation of data to both diagnose and manage patients. The underpinning cognitive process of CR is explained by dual information processing theory, whereby cognitive processes initially default to NAR, intuitive or type 1 reasoning if the situation or patient problem is recognised and AR or type 2 reasoning if something doesn't fit and working memory is employed in this circumstance. Accurate CR is supported by illness scripts which are mental models of diseases and develop through a clinician's lifetime with increasing knowledge and experience (Schmidt HG, 2007). The process of CR is affected by various contexts that impact outcome including diagnosis and management of the patient. Accuracy of CR is important to avoid error and the cost implications and patient safety implications associated with this. The GMC mandates CR is developed in medical students where providing a firm foundation of knowledge and skill is important for further development in post-graduate training. Education is vital for development of CR which is discussed further in chapter 2.

Chapter 2: Developing clinical reasoning

Clinical reasoning development through educational theory

CR requires acquisition of biomedical and clinical knowledge, which is structured in memory as illness scripts, to be retrieved and processed during a clinical encounter using either type 1 or 2 reasoning. When this explanation is used as the underpinning of CR, education is offered as crucial for CR development and improvement (Norman et al., 2017). As indicated in Chapter 1, there is little evidence that CR itself can be taught directly (Gruppen and Frohna, 2002, Norman et al., 2017). Studies which highlighted error as being more frequent in 'common' cases where the clinicians were determined to have the knowledge but still failed to find the correct diagnosis (Graber et al., 2005a) suggested that errors in reasoning could be to blame. However, research into cognitive biases have found that attempting to alter the way people think about clinical problems has no impact on error rates (Croskerry, 2003, Sherbino et al., 2014). Norman et al (2017) support this view, highlighting that small but consistent benefits can be gained only by focusing on strategies that aid knowledge organisation, illuminating further both the role of knowledge structure in illness scripts and the vital part that education plays. The view of this research is that CR develops through learning and combining both CR and broader educational theories allows us to predict which educational strategies will be most valuable. Understanding these approaches is important to allow educators to provide the most effective educational opportunities for students to develop CR and in the longer term, improve diagnosis and management of patients (Graber et al., 2018). However, understanding these approaches alone is potentially insufficient when considering that education to develop CR is delivered in a real-world setting, impacted by context, similarly to how context interacts with the CR process itself. This research studies undergraduate CR development in the real world,

considering the impact of context on educational interventions and activities theorised to be important for CR and the potential effects on CR development.

Significant value was placed on understanding CR development through theory and mid-range, educational theories were selected based upon their ability to predict and deepen understanding of how CR, as conceptualised in Figure 2, develops. Specific theories were identified through the researchers own learning including background reading, participation in Medical Education Masters' degree modules in educational theories and through discussion with the research supervisory team. Theories were selected when the researcher perceived they would be helpful to increase understanding. CR and its development is bound within context, so theories which enabled understanding of different contexts, or factors impacting CR development, were included, again by background literature searching and discussion with experts in the supervisory team. This section details the educational theories which underpin CR development, the conceptualisation of CR development utilised in this research and the literature considering the role of context in CR education.

Script theory and knowledge acquisition

Script theory has been discussed in chapter 1 to explain both the structure of knowledge in memory which supports the CR process and justify the conceptualisation of CR in this research. In this section, the implications of script theory for CR development are described. To recap, knowledge, whether that be factual, procedural, conceptual or metacognitive (Krathwohl, 2002), is acquired, encapsulated and represented as a schema or script, a mental model of knowledge. Specific to clinically relevant knowledge, this mental representation of knowledge is termed an illness script (Lubarsky et al., 2015).

Further knowledge and experiences build on existing schemas or generate new ones and refine them over time. This refinement is proposed to occur through the process of assimilation, fitting new information with existing schemas and accommodation, the generation of new schemas or adaptation of existing ones based on the acquisition of new knowledge (McLeod, 2022). CR is underpinned by individually constructed illness scripts through acquisition of knowledge and experience which highlights the idiosyncrasy of CR (Sefton et al., 2008) as everyone will have unique experiences throughout medical training. This perspective fits with the observation that doctors do manage patients in different but still acceptable and safe ways. Given that illness scripts are refined through experience, this has implications for education and led some to suggest the most effective way to develop CR is through seeing large numbers of patients and large numbers of problems (Schmidt HG, 2007). This view is based in sound educational theory but whether this may not be implemented effectively in real educational and clinical environments if opportunities for hands-on experiences are limited (Rencic, 2011).

Once illness scripts are developed, in order for them to be useful for CR they must be retrieved from memory and the knowledge then applied to the clinical problem, this is called illness script activation. Activation of illness scripts, that is the process through which illness scripts are brought to conscious attention, is normally a subconscious process (Koufidis et al., 2021). When multiple illness scripts are activated or no illness scripts appear to fit the clinical presentation or picture, a conscious search for information occurs which will subsequently activate the illness script of best fit to the problem. The processes of retrieval of illness scripts, either subconsciously or via a deliberate search for information is proposed to be the underpinning for type 1 or type 2 reasoning processes, that is in this research, the storage of knowledge in memory underpins the dual process theory of CR (Norman, 2009). This claim is supported by research that shows strategies that aid application or reorganisation of knowledge aid diagnostic accuracy as an outcome of CR

(Monteiro and Norman, 2013). Using accurate medical language or semantic qualifiers (Bordage, 2007, Cooper and Frain, 2016) when representing and articulating the patients problem is vital to ensuing that both knowledge stored effectively in the correct script and that relevant scripts are activated. Semantic qualifiers are dichotomous descriptors used to translate the patient narrative (Koufidis et al., 2021), such as acute or chronic, intermittent or constant. Given that experts have been shown to use semantic qualifiers more frequently in their problem representation (Koufidis et al., 2021), this has led some authors to suggest that expertise in CR is "fluent problem representation" (Gruppen and Frohna, 2002). Therefore, during CR development, acknowledging and encouraging students to assign the appropriate language to the illness scripts is paramount. For example, a script of appendicitis with the problem representation of acute right iliac fossa pain will only be activated if the student has an illness script developed with such an articulated representation of appendicitis. If their illness script is less developed or the key medical terminology is not utilised, the script is less likely to be activated when they are faced with a patient with acute right iliac fossa pain. Semantic qualifiers and accurate medical terminology can be encouraged by medical teachers when students present and discuss patient cases (Cooper and Frain, 2016). Similarly encouraging a summary statement can also promote use of semantic qualifiers which aids organisation and refinement of knowledge in illness scripts. Overall, the importance of knowledge to CR and more so, the importance of how this knowledge is stored as illness scripts has implications for education; namely consideration of how knowledge is best acquired and the most effective educational interventions that aid structuring of this knowledge in memory.

Given that knowledge is vital and that medical students commence medical training with limited knowledge, acquisition of basic biomedical science knowledge is clearly important. Some curricula advocate for problem-based learning (PBL) approaches where basic biomedical, physiological and pathological knowledge is acquired alongside clinically relevant information

whereas traditional curricula focus on basic knowledge acquisition first, followed by learning how to apply it to patient's problems by way of clinical attachments. Evidence for the effectiveness of these approaches to development of CR is varied. Khin-Htun and Thu (2019) found a difference in CR ability when students had been exposed to either a PBL or traditional curricula at a mid-point of training but no difference once the students had completed medical school indicating that the curricula type doesn't have long term impact on CR ability. Some studies have shown that in fact traditional curricula provide advantage to CR ability compared to PBL approaches (Goss et al., 2011), but overall, evidence to suggest one curricula approach over another to promote CR ability is lacking. As Kilroy (2004) highlights, despite the lack of evidence for promoting knowledge acquisition in a particular curricula format, students who undertaken PBL courses have opportunity to demonstrate self-direction over their learning and this may translate into more intrinsically motivated and confident learners. These characteristics are presumed to translate in better educational outcomes but there is no specific evidence for CR ability in students. Despite the lack of evidence for a particular form of curriculum being superior in terms of knowledge acquisition and CR development, there have been suggestions of strategies that are positively associated with knowledge acquisition (Weinstein et al., 2018, Brown et al., 2014) which could be theorised to promote better foundations of knowledge on which to develop illness scripts.

Knowledge acquisition and learning strategies

Knowledge acquisition and development of its structure in memory is attested to be the most important educational intervention available to improve CR (Norman et al., 2017, Brush et al., 2022). As described, knowledge is stored as illness scripts, encapsulated mental representations of knowledge, which are refined with increasing knowledge acquisition and experience.

Learners of all levels, from absolute novice to expert, will store knowledge in this way. For knowledge to be effectively stored in long term memory and therefore be amenable for retrieval when it is required, such as in a CR task, several strategies have been proposed and proven to be effective (Brown et al., 2014, Weinstein et al., 2018, Richmond et al., 2019). These strategies and the accompanying description and examples are shown in Table 3.

Strategy	***Description and examples***
Spaced practice	Spacing out teaching encounters both reduces cognitive load and promotes retrieval of information
Retrieval practice	Practicing retrieving information from memory including self-assessment, promoting effortful recall from learners and repeated testing
Mixed practice (interleaving)	Mixing different topics together increases learners' ability to discriminate between similar but different problems (such as learning by patient presentation rather than disease)
Elaboration	Explaining something in as much detail as possible in your own words such as encouraging self-explanation and linking the patients' problem to the basic sciences
Dual coding	Using pictures/concept maps to explain words. Concept maps also promote learning similarities, dissimilarities, and connections between different conditions
Concrete examples	Relating knowledge to a real-life event or experience (such as a patient encounter)

Table 3: Learning strategies adapted from the learning scientists (Sumeracki and Weinstein, 2017)

These learning strategies can be applied to a students' self-directed learning or within educational activities. However, awareness of the strategies beyond the cognitive learning sciences is often limited (Weinstein et al., 2018), resulting in students who do not understand how to learn (Richmond et al., 2019) and teachers who do not apply the strategies to teaching activities. The educational implication of this is that raising awareness of the how we learn and encouragement to use the strategies, both for students and teachers, may have a positive benefit in improving long term knowledge acquisition. Knowledge acquisition alone is insufficient to develop CR, but is required to initiate the development process considering illness scripts are the underpinning structures in memory that facilitate the process of CR. Once basic knowledge is acquired, learners progress to experiences that enable constant revision and restructuring of illness scripts. For an experience to best enable further knowledge acquisition in a way that will build and revise illness scripts effectively, several theories have been suggested. These theories can apply to a broad range of educational activities but do not focus specifically on CR development or knowledge acquisition and illness script development.

Expertise theory

Students commencing medical training in the UK, do so most frequently with limited previous knowledge or experience within any specific medical domain. Some graduate entry medical (GEM) students may have specific skills in certain domains linked to their previous training or employment, but most frequently students at the beginning of training are novices. Whilst students rarely become experts in any clinical domain during medical school, expertise

theory is concerned with the development outstanding ability within a specified domain (Ericsson and Smith, 1991) and has useful implications for development of CR even at an undergraduate level. Striving for excellence in education is optimum to generate the best outcomes and expertise theory implies that reaching outstanding ability is possible when certain strategies to development in that domain are applied. Specific to CR, a marker of expertise development is the increasing accuracy of NAR underpinned by well refined illness scripts, but expertise within CR is not the use of NAR alone and, as Croskerry (2020b) notes, a true marker of expertise is knowing when the clinical problem does not fit. Whilst simple tasks such as driving a car can be practiced to the point of automation quite satisfactorily (Ericsson, 2004), with complex tasks such automation without attention can lead to intuitive judgments being left unchecked (Peña, 2010, Croskerry, 2020b). Put simply, NAR is a component of expertise development, but NAR is not a hallmark of expertise. In this respect, using both NAR and analytical reasoning (AR) could be seen as vital for expertise within CR (Brush et al., 2017). Even though medical students are not expected to become expert in CR by the end of their undergraduate studies, higher performing students have been found to structure knowledge around the clinical problem at hand rather than generically (Coderre et al., 2009), in other words they are developing illness scripts and beginning the path to expertise. If medical students who perform better, structure knowledge using illness scripts, educational approaches which better develop these, and therefore expertise that follows, is proposed to be key to develop CR most effectively (Graber, 2009). In other words, since students are not expected to become experts in any clinical domain but do demonstrate some of the cognitive development associated with developing expertise, this research describes CR development as a progression from novice to experienced.

Development of expertise is a lengthy pursuit and said to occur through experience but, not all experience will lead to development of expertise (Ericsson and Smith, 1991). Expertise requires acquisition of knowledge and

skills necessary for optimum performance but also through a cognitively active and effortful process which has been named 'deliberate practice' (Ericsson, 2004). Deliberate practice has several components which are theorised to promote more effective learning. Different authors have suggested a range of educational implications of deliberate practice but in common with them all are the recommendations for focussed and repetitive practice, frequent feedback and reflection on performance and opportunities to repeat practice with gradual improvements, (Ericsson, 2004, McGaghie et al., 2011, Rencic, 2011) all of which can be applied to CR development as well other educational activities. Rencic (2011), within their recommendations of teaching expertise in CR, highlight that using mental practice frequently is a way of overcoming shortages in contact with real patients or when specific presentations of diseases are not readily available. This recommendation serves to illuminate that even when hands-on experiences are limited with real patients, principles of deliberate practice can still continue. Mental practice is a form a cognitive simulation and can be used individually or in groups (Kassirer, 2010) which may be even more valuable educationally if feedback and reflection is incorporated. Mental practice may be undertaken spontaneously by some students, but encouragement to do so by clinical educators would be valuable (Rencic, 2011).

In summary, development of expertise within CR is the transition from novice, utilising mostly AR, to expertise utilising accurate NAR and some AR supported by developed and refined illness scripts. Development of expertise within any domain is stipulated to take more than 10 years of experience (Ericsson, 2004), but the exact temporal duration is related to the learners experiences and, perhaps more importantly, the educational value of them. Students are not expected to become experts, but the principles of deliberate practice enable educational activities to be the most valuable, accelerating the development of illness scripts and building stronger foundations. Advice to ensure that students make the most of all educational opportunities that are given to them (Rencic, 2011), adheres to principles suggested by expertise

theory. Whether this is possible however within the current educational and clinical environment is unknown and part of the purpose of this research.

Cognitive load theory

Cognitive Load Theory (CLT) is valuable to consider in all educational interventions, particularly for novices, where undeveloped scripts mean that individual pieces of information need to be considered in working memory rather as a whole following activation of the script. CLT proposes that cognitive processes related to the task provide the learner with intrinsic load and there is also a cognitive load from extrinsic sources and a germane load associated with the learning of the material at hand (Young et al., 2014) as shown in Figure 3.

Figure 3: Cognitive Load Theory - Intrinsic, Extraneous and Germane load

For novice learners, intrinsic load related to the task itself can be high and therefore efforts to simplify instructions and reduce extraneous load, such as distractions, increases the available cognitive space for learning itself. In more experienced learners, the intrinsic load of the task may be reduced meaning that more capacity is available to cope with distractions and not lose the educational benefit. In CR development, authors have suggested that for novice learners, information necessary for CR is provided to the student as a whole case rather than the serial release of information (Schmidt and Mamede, 2015) that might be more useful for a more experienced student. CLT supports this approach as the intrinsic load from the task is reduced or simplified as all the required information to solve the case is immediately available. This would not be the case if the student needed to gather this information sequentially. Presentation of whole cases for novices therefore allows more cognitive space for the germane load of learning. In more experienced students, serial release of information is more likely to be valuable as they experience less intrinsic load related to the task and practising gathering information whilst processing the meaning is more akin to reality.

Experiential learning theory

Experiential learning (Kolb, 1984) posits that learning occurs within experience followed by a period of reflection and practice that enables development for the next experience in a cyclical fashion as shown in Figure 4.

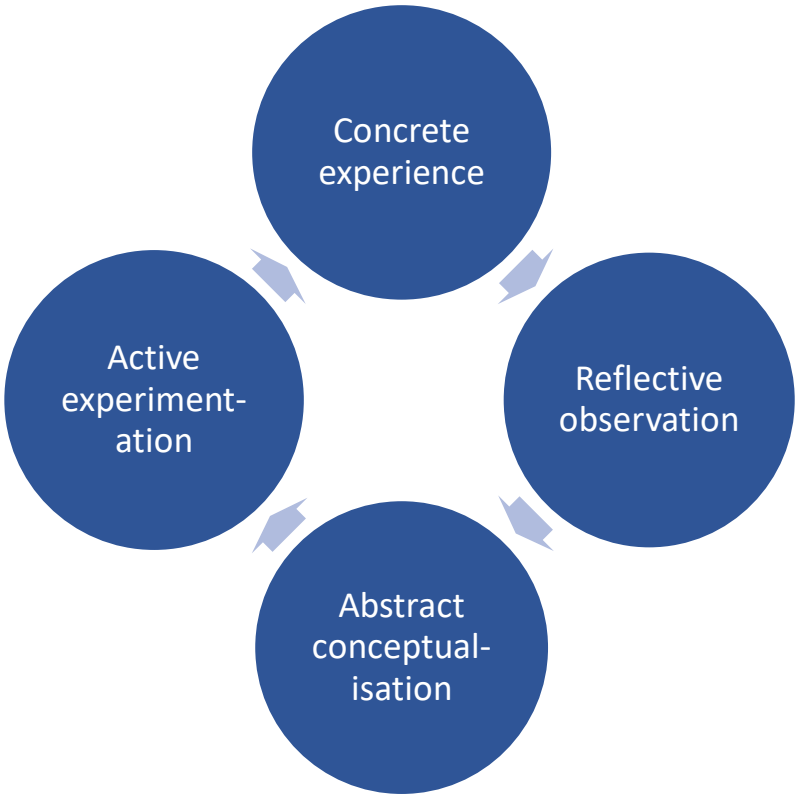

Figure 4: Cycle of experiential learning adapted from Kolb (1984)

This theory supports illness script development as experiences are required to develop holistic mental representations of disease but further describes the ways in which learning through experience occurs. Some of the principles of deliberate practice are similar to how experiential learning aids the development of educational interventions, except for deliberate practice, there is a focus on a specific aspect of the task. When related to CR development, a teacher may provide feedback on performance and encourage the drawing of connections between cases, share their own experiences and rationales and ask questions that encourage thinking about the case (Smith and Irby, 1997, Lubarsky et al., 2015). Providing feedback where an error has been made in the initial experience can be particularly valuable (Eva, 2009). Reflection on a clinical case, a component of experiential learning, has been proposed to aid CR development through activating prior knowledge and allowing consideration of multiple diagnostic possibilities (Mamede et al., 2012, Mamede and Schmidt, 2022). Students may also be advised to self-reflect or

talk through the case to learn from the experience (Chamberland et al., 2011). During the experience of CR, the role of teachers observing and identifying potential CR difficulties is important (Audetat et al., 2013). Part of providing remediation for students felt to have CR difficulties may be a clinician purposefully explaining their reasoning processes to the student (Audetat et al., 2013) using medical terminology. Expert clinicians, however, do frequently use non-analytical reasoning (NAR) which can be inaccessible to novices and so care must be taken to ensure explanation is appropriate for the students' level and to not assume students will learn through observation alone in all instances (Sefton et al., 2008). The educational approach of making a clinicians illness scripts transparent by talking through their reasoning process is suggested to aid understanding of the clinical case by enabling assimilation of knowledge into the students underdeveloped illness scripts (Lubarsky et al., 2015). All these approaches ensure that a students' experience is valuable educationally by enabling knowledge acquisition and subsequent development of illness scripts. These educational interventions, whilst based in sound educational theory, are potentially more challenging to implement in real world settings.

Dual information processing theory

This theory has been described in chapter 1 and mentioned here to consider the educational implications of the theory for CR development. Some authors have suggested encouraging both AR and NAR to enhance accuracy of diagnosis. Ark, Brooks and Eva (2006) found that, even amongst novices, student's diagnostic accuracy was enhanced using this technique. They conclude that we should embrace the role of NAR in clinical decision making and, rather than encourage students to always divert to AR, we should nurture students' intuitive skills. This conclusion was shared by Eva et al (2007) again focusing on novices diagnosing ECGs who found in favour of encouraging both modes of reasoning. The main criticism of these studies is their experimental

nature which may makes extrapolation to real-life scenarios challenging. In addition, from an educational perspective, encouraging specific reasoning processes may not be possible. As Dhaliwal (2016) notes, students, or doctors, may not be able to consciously choose to think about a problem intuitively or analytically, rather the nature of the problem and the degree of familiarity with it will dictate the reasoning processes used. The degree to which encouraging different modes of reasoning is beneficial to medical students within an undergraduate teaching setting is unknown but will be considered in this thesis.

As a method to encourage AR to overcome cognitive biases and the subsequent potential diagnostic errors, cognitive forcing strategies have been proposed (Croskerry et al., 2013a, Croskerry et al., 2013b). These strategies involve knowing about cognitive biases and employing AR to overcome them. Whilst remembering that experimental studies in non-clinical settings makes the transferability of the findings to clinical practice limited, there is still no evidence that these strategies work to improve diagnosis as an outcome of CR or to develop CR in students (Sherbino et al., 2014). Given that we have demonstrated that NAR is unconscious and deeply based in knowledge, it is not surprising this is the case. If students are aware of cognitive biases, whilst there is no evidence to suggest that this will improve their CR in the moment, whether this aids students' reflection on their practice and the subsequent value to CR development is unknown.

Several educational theories, their implications for educational interventions and the gaps in the literature have been described. Overall, the key gap is how these educational interventions effectively develop CR in the real world. Thus follows a review of the literature regarding factors that impact development of CR in real world settings.

Situativity and cognitive flexibility theory

As highlighted, education in clinical settings poses several challenges (Woolliscroft, 2002) including the interacting components and contexts that impact on both CR as a process and the development of CR through education. Situativity theory highlights situation and context specificity (Durning and Artino, 2011) which has implications for educational interventions and posits that learning should take place in authentic contexts, learning should take place through social interactions and information should be presented in a variety of ways. In addition to the educational implications, Durning and Artino (2011) recognise that contexts or factors related to the physician, patient and the encounter impact the clinical outcome of CR as shown in Figure 5. These factors are described within the clinical interaction but are felt to also impact educational instruction and development of CR.

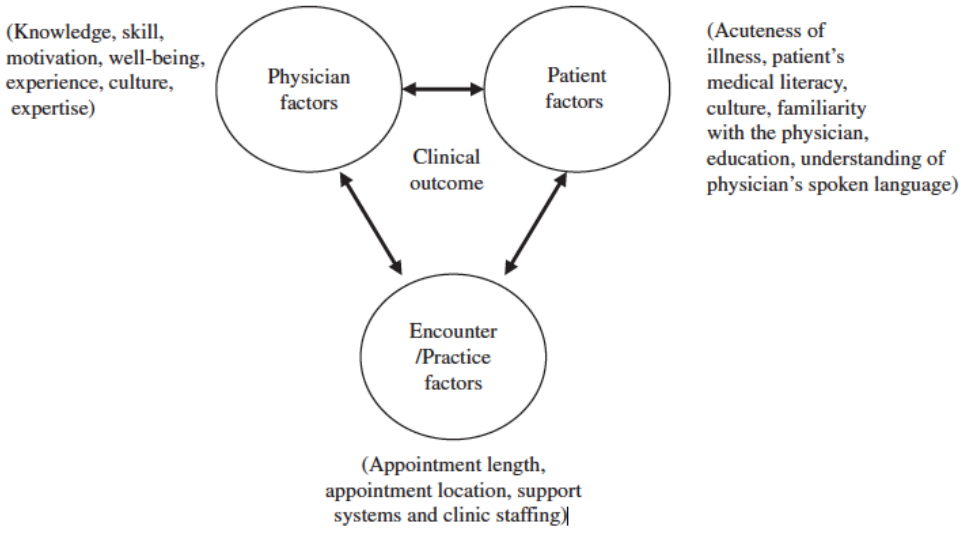

Figure 5: Situativity theory in the clinical encounter (Durning SJ, 2011)

In addition to the contexts and factors that affect CR itself, it is well documented that the context in which learning occurs affects transfer to applying that knowledge in different contexts (Durning SJ, 2011). For example, learning about the management of an acute respiratory problem in a paediatric ward will not be the same as learning about the same presentation in a GP practice. Situativity theories support the notion that learning about reasoning itself will not benefit the student with reasoning in context specific situations as the knowledge will not be transferable to different contexts. This idea is supported by cognitive flexibility theory (CFT) (Spiro et al., 1988, Culatta, 2015). CFT is concerned with transfer of knowledge beyond the original learning situation and, similarly to situativity theories, recommends utilising multiple iterations of similar cases to teach. This educational approach develops flexibility in the way people think in real life scenarios where their approach will need to be adapted to changing circumstances. With respect to CR education, CFT suggests that it is important to portray medical cases in many ways to reflect the nature of real clinical practice. When educational activities are broad and cover a wide range of different presentations and conditions in differing situations and contexts, this enables students to develop more complete and refined illness scripts. When confronted with patient presentations in future, the knowledge base will be broader, more easily accessible and this is proposed to translate to more accurate CR and the subsequent accuracy of outcomes of diagnosis and management that impact patient care.

Situativity theory also highlights that factors or contexts impact outcomes (Durning and Artino, 2011), a fact that can also be applied to interventions, including CR development through education. Where interventions are impacted by context, they can be classified as complex (Skivington et al., 2021) and a more detailed description of what makes an intervention complex and how this impacts research is discussed in chapter 3. In any educational intervention, but specifically one pertaining to a student learning in a clinical setting, Woolliscroft (2002) suggest that what is learned in

the clinical setting is shaped by the student, the instructor and the patient. Furthermore, the context of where the learning takes place acknowledges the role of the wider educational and organisational factors that impact outcome. Harden and Laidlaw (2012) make suggestions throughout their book on essential skills for medical teachers, that the factors pertaining to the student, teacher and educational environment impact educational outcome. With respect to CR development which takes place across a wide range of educational settings and may or may not include patients, broadly factors pertaining to the student, the teacher and the wider educational or organisational environment were theorised to impact educational interventions as shown in Figure 6.

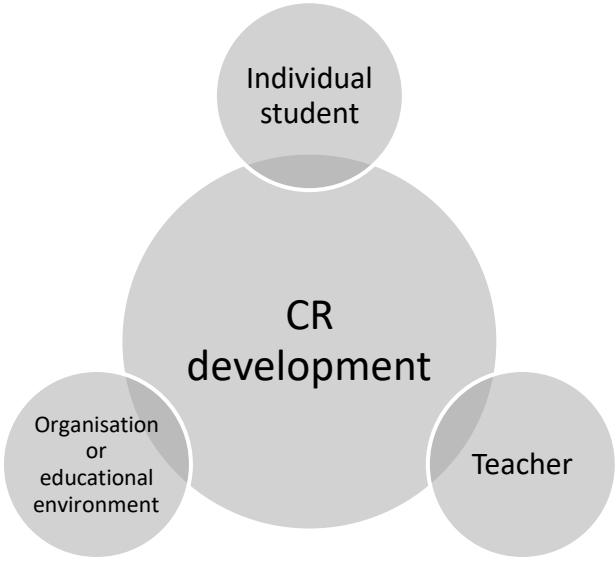

Figure 6: Contexts or factors impacting on educational interventions to develop CR

This section has proposed that, although educational interventions to develop CR are well established, whether they do when implemented in the real world is contingent on, and affected by, context. Although the literature has considered how various factors might impact educational interventions,

none have assimilated the body of CR development educational literature with the effect of context on educational outcome.

Conceptual model of clinical reasoning development

To conclude, CR is a cognitive process requiring mental representations of disease called illness scripts which develop through acquisition of knowledge and experience, with accompanying reflection and feedback (Schmidt HG, 2007). With increasing experience and development of illness scripts, cognitive processes become increasing non-analytical, with analytical processing to confirm decisions or when something doesn't fit the expected pattern. This development is underpinned by educational theories including script theory, strategies of knowledge acquisition, deliberate practice, cognitive load theory and experiential learning. In addition, context related to the student themselves, the teacher and environment interacts with educational interventions and activities that develop CR. This makes education to develop CR complex with many interacting components that potentially impact outcome, both positively and negatively. Development of CR conceptualised to occur within a specific clinical domain as demonstrated in Figure 7.

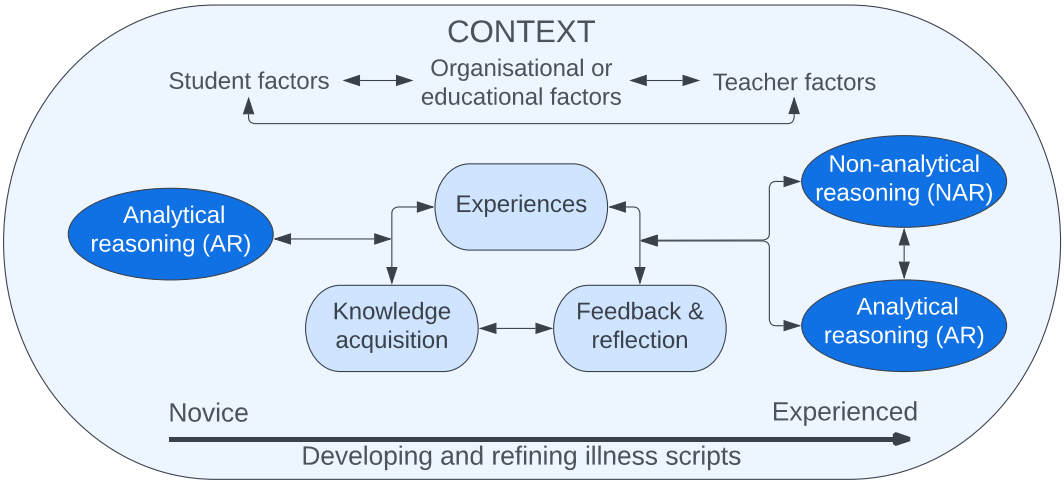

Figure 7: Development of CR within a clinical domain

The gap in the literature

Methods of teaching CR have been well reported throughout the medical education literature (Furney et al., 2001, Eva et al., 2007, Wolpaw et al., 2009, Gay et al., 2013, Schmidt and Mamede, 2015, Cooper et al., 2021). These studies highlight CR teaching programmes (Gay et al., 2013), approaches to aid learning from experiences such as the one minute preceptor (Furney et al., 2001) or SNAPPS (Wolpaw et al., 2009) and techniques to develop illness scripts which vary according to experience of the student (Schmidt and Mamede, 2015). In addition, the educational theory literature explains why developing CR, as underpinned by illness scripts and dual processing theory, requires knowledge acquisition, experiences and feedback or reflection. However, whether these educational interventions can be implemented effectively to all students in the educational and clinical settings where students are taught is proposed to be challenging (Woolliscroft, 2002). Furthermore, the contexts and circumstances necessary to ensure educational interventions develop CR effectively in reality are understudied and are the focus of the research presented here. Whilst studies have considered potential factors that impact educational interventions more generally or imply that different approaches should be taken in different situations, there is no published literature that assimilates this body of research with the development of CR through educational interventions. This research will utilise realist methodology which will be explained and justified in Chapter 3. Realist methodological approaches, whilst utilised in medical education (Wong et al., 2010, Kehoe et al., 2016), have not been used to investigate CR development. Realist research approaches focus on understanding the contexts that affect interventions' outcomes. This approach enables a deeper understanding of CR development through education. The research findings will provide

recommendations which will enable medical educators to develop interventions whilst being considerate of the situations and circumstances in which the intervention is likely to succeed. It will also enable understanding of why particular interventions might fail in certain circumstances or for certain students and what might be done to overcome this, including development of alternative interventions that might be more effective in certain contexts. Development of a strong foundation of knowledge and CR ability in medical students is proposed to be vital to ensure continuing development into post-graduate medical education (PGME) which then has a direct impact on patient care and safety. This gap is articulated in the following section as a research question, aim and objectives of the research.

Research question, aim and objectives

The overall research question is:

- In what ways do educational interventions develop clinical reasoning ability among undergraduate medical students? What works for whom, in what circumstances and why?

Aim:

- To evaluate educational interventions that develop clinical reasoning ability among undergraduate medical students using a realist methodological approach.

Objectives:

- To conduct a realist review of the literature of educational interventions to develop clinical reasoning in medical students.

- To perform a realist evaluation of the educational interventions that develop clinical reasoning among undergraduate medical students at Nottingham Medical School using realist qualitative methods.

In summary, real CR development occurs within context which will affect outcome. Methods of evaluation that do not consider the complexity of educational interventions will not be able to determine the reasons for success or failure. This research considers context as a key element responsible for educational success and this is reflected in the chosen research methodology. This approach, its philosophical underpinnings, methodological assumptions, and the specific application to this research are described in Chapter 3.

Summary of chapter

CR development is promoted by acquisition of knowledge and experiences which collectively support illness script development. Experts in a domain demonstrate highly accurate CR, therefore the educational recommendations to develop expertise including the application of principles of deliberate practice are important. Educational theories that are proposed to support illness script and subsequent CR ability were described including the educational interventions and activities supported by those theories. Educational interventions to develop CR in medical students are well described but implementation in real educational and clinical settings may impact their effectiveness because interventions in the real world are impacted by various contexts. Context therefore needs to be understood to effectively evaluate CR development through education. The chosen research approach of realist review and evaluation focuses on evaluation of complex interventions and is described in the next chapter.

Chapter 3: Methodology

This chapter introduces CR development as a complex intervention and justifies the use of realist research. The philosophical underpinnings of the realist methodological approach used in this research is introduced. General philosophical and methodological considerations are discussed followed a brief description of the ways the realist approach is used in this research.

Embracing complexity in education and research

Complex interventions can be defined as "intervention[s] that contain several interacting components" (Craig et al., 2006, Skivington et al., 2021). There are several elements that may be considered as rendering an intervention complex and medical education interventions demonstrate many features of complexity (Mattick et al., 2013) as shown in Table 4.

What makes an intervention complex?	**Examples from medical education**
Number of and interactions between components within experimental and control interventions	Medical education involves many different components—lectures, clinical placements, PBL etc. The learning environments differ hugely in different parts of the curriculum. Student exposure to different aspects varies
Number and difficulty of behaviours required by those delivering or receiving the intervention	*Teachers* need to be knowledgeable, enthusiastic and able to assess and give feedback to students but must adapt to different environments, student groups and teaching modes.

	Students need to attend, engage and learn in a wide variety of different circumstances, and in interactions with different teachers
Number of groups or organisational levels targeted by the intervention	Student groups vary, and usually contain a mixture of people of different age and background. Medical education involves partner organisations (such as the NHS in the UK) in delivering the curriculum
Number and variability of outcomes	Summative assessments of knowledge and skill. Professional outcome measures (such as GMC registration). Ability to work in health care groups
Degree of flexibility or tailoring of the intervention permitted	It is accepted that no two students can get quite the same experience. Tailoring to individual students who may need remediation is usually undertaken

Table 4: Medical research council definition of a complex intervention and examples from medical education (Mattick et al., 2013, Craig et al., 2006)

CR development requires a wide range of interventions, large numbers of people and organisations implementing them, and outcomes are variable. CR development through education was therefore viewed as a complex intervention within this research.

Complexity has also been described when interventions are introduced into complex social systems such that it is not the intervention itself that is complex, but the complexity of the system in which they are implemented (Moore et al., 2019). Pawson (2004) describes complex social interventions as being based in theory, involving the actions of people, encompassing multiple steps or processes which are non-linear, embedded within open social systems with varying contexts and that they are prone to modification. This highlights

that both components related to the intervention and the system in which it is implemented and operates are part of the definition of complexity. In the case of education, and more specifically CR development, both the intervention itself and the social system in which it is delivered are viewed as complex.

When educational interventions are viewed as complex, Mattick et al (2013) note that this has implications for medical education research, concluding that "medical education researchers [should] work within complex interventions framework[s]". Cook et al (2008) found in an analysis of 105 medical education articles that the majority focused on the description of the education intervention or its justification; what was done and did it work. Only 12% were clarification studies seeking to understand why a particular intervention works or not. They concluded that further research into clarification of educational interventions was required to advance the field of medical education research. This view was supported by the recommendation from the MRC report on developing and evaluating complex interventions that we should have a good theoretical understanding of *how* the intervention leads to the outcomes (Craig et al., 2006). Furthermore, a recent update to the Medical Research Council (MRC) guidance (Skivington et al., 2021) advocates for consideration of the role of context and inclusion of programme theory, supporting the application of approaches that acknowledge these topics.

Within CR research, much of the literature pertains to experimental studies that are purposefully devoid of context to detect only the effect of the intervention in question. Whilst these studies have a place in understanding which interventions *might* work, their effect when delivered within real-life educational or clinical settings is often unknown or unpredictable. There has been a call to study CR "in the wild" (Gruppen and Frohna, 2002, Wears and Nemeth, 2007), thereby embracing the role of context within CR which sits comfortably with the most recent MRC recommendations (Skivington et al.,

2021). Overall, viewing CR development though education as a complex intervention within a complex social system, dictates that research utilise approaches that embrace that complexity to further understanding.

A realist research approach allows for consideration of not just 'what works' but also why, how, for whom and in what circumstances (Pawson, 2006). This research approach was first described in the context of social science research, specifically criminology, by Ray Pawson and Nick Tilley (Pawson, 2006). Their original research related to social interventions to reduce crime; for example understanding the mechanisms behind how CCTV prevents crime (Tilley, 1993). This approach has been used within medical education including Kehoe et al (2016) who study transition of international medical graduates to UK practice, Wong et al (2010) in their research into internet based medical education and Brennan et al (2017) who investigate appraisal of doctors. Furthermore, Wong et al (2012) highlight how useful realist approaches could be in medical education research given the complex nature of interventions in this field. Realist research methodology specifically focuses on understanding the reasons why and how outcomes occur and in which situations and circumstances they are likely to be successful. This approach was felt to be most appropriate for studying educational interventions to develop CR. The following sections will outline the realist approach to research and its philosophical underpinning and assumptions.

The realist philosophy of science

Traditionally research is defined by 1 of 2 possible paradigms, positivist, or interpretivist. The former being the research paradigm of the sciences and believing in a single reality and that knowledge can be defined and measured. We refer to this as a quantitative style of research. The latter paradigm sees

that reality is multiple and socially constructed, as such there is not a true reality and the measure of it therefore is dependent on the relationship between the observer or researcher and the participants. Reality in this case needs to be interpreted and data obtained from one situation may not be generalizable to all populations, organisations or situations. This research is qualitative in nature.

A realist approach takes a view that is somewhere between positivist and interpretivist; that there is a singular reality but the approaches to its measurement are fallible and different contexts mean that the outcomes are likewise variable (see Table 5). The realist research approach seeks to discover how these different contexts and mechanisms affect programmes, such as educational interventions, and discover how the outcomes may differ. This enables us to uncover how do interventions work, why they work, in what circumstances do they work and for whom (Wong et al., 2010). This approach is useful for understanding complex programmes where multiple factors interact and affect the outcome of the intervention.

	Positivist	**Realist**	**Interpretivist**
Ontology (the nature of reality)	Singular	Singular but levels of reality	Multiple
Epistemology (the nature of knowledge)	Measurable and objective	Not all measurable	Subjective and impossible to measure
Commonly used methods in research	Quantitative	Both Quantitative and qualitative	Qualitative

Table 5: Comparison of the philosophy of common research paradigms

The realist research paradigm has philosophical roots in critical realism (Bhaskar, 2008) and so an account of the philosophical assumptions and underpinnings of critical realism follows.

Critical realism

Bhaskar's work into critical realism (Bhaskar, 2008) paved the way for the development of the research paradigm of applied scientific realism as used in this research. Bhaskar was a proponent for progression away from positivism where ontology and epistemology were conflated (what is known is the same as what is true) and towards a realistic understanding of not just what happens in the world but why this is the case. As such, he advocated for a clear delineation between ontology and epistemology; he advocated for the idea that something can be real even though it is unobservable or unmeasurable. This is a deviation away from positivist views of constant conjunction and successionist views of causation, where the truth can be known when causation is proven. In critical realist philosophy, constant conjunctions are rejected as these can only be expected in closed system, in other words, when confounding variables are accounted for. In open, or social, systems, mechanisms are responsible for generative causality where patterns of outcome may be predicted but will not be constant dependent on context.

Bhaskar proposed a stratified view of ontology into the domains of the real, actual, and empirical, see Table 6. Positivist philosophical views conflate the empirical and therefore experienced, measurable or observable with the truth, known as the epistemic fallacy. Deeper, unobservable and unmeasurable levels of reality exist and drive behaviour and outcomes but epistemologically are not amenable to measurement. Experiences, that is what we can measure and observe, are in the domain of the empirical. Events occur whether we are

aware of them or not and are in the domain of the actual. Only the domain of the real are the underlying mechanisms that generate change and behaviour and exist regardless of our inability to observe them.

	Real	Actual	Empirical
Mechanisms	X		
Events	X	X	
Experiences	X	X	X

Table 6: Adapted from Bhaskar (Bhaskar, 2008); Stratified reality and domains of the real, actual and empirical

These mechanisms generate causation and include constructs of various types including powers such as potential to learn, forces such as gravity, emotions such as love or reasoning, or cognition such as engagement (Westhorp, 2018). What holds true for all mechanisms is that they exist in the ontological domain of the real and are unobservable and unmeasurable, yet we can infer their existence through observations we can make and experiences we have in the domain of the empirical.

Critical realism has been criticised as a philosophical position in need of a method. Williams (2017) suggest that realist research approaches as advocated by Pawson and Tilley (1997), can “bridge the philosophy with practice”(Williams et al., 2017). What follows is therefore a description of the realist research approaches as used in this research.

Applied scientific realism: Realist evaluation and synthesis

Pawson and Tilley's realist approach draws on the philosophy of critical realism attributed to Bhaskar (2008) but allows the philosophical position to be operationalised in the research and evaluation of interventions and programmes so that they may be better understood (Williams et al., 2017). Both the philosophy of critical realism and realism described by Pawson and Tilley (1997) assert that is it not the interventions themselves that produce outcomes but in fact human agency and their own volition. This is well suited to education, as the educational interventions produce different outcomes for different students, so an understanding of the contexts that affect differences and the mechanisms producing these is invaluable to understanding *why* an intervention is working or not (Wong et al., 2012). Understanding the contexts in which programmes work or do not work is particularly helpful when one wishes to move the intervention to a different context as they will be able to predict whether it is likely to succeed or fail (Jagosh, 2018). One would also be able to retrospectively understand why an intervention had failed once it had been moved to a different context.

Pawson and Tilley (1997) outline that realist research follows the same lines of enquiry as any scientific study and use 'The wheel of science' to demonstrate the parallels between any scientific enquiry and that which employs realist techniques as shown in Figure 8.

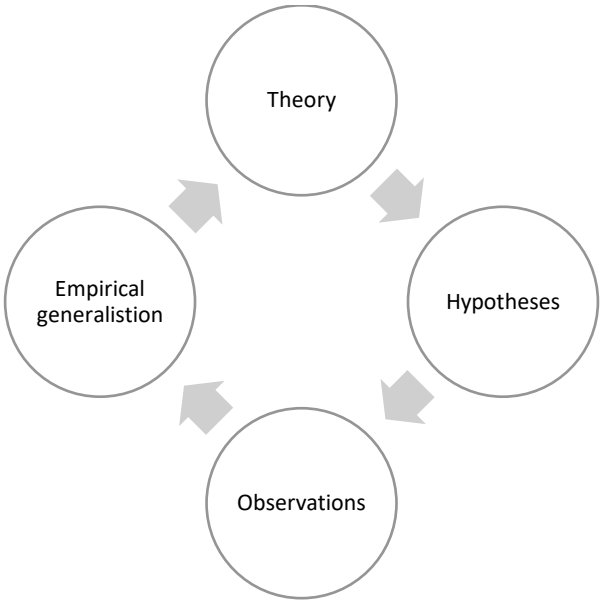

Figure 8: The Wheel of Science (after Wallace, 1971) from Pawson and Tilley (1997)

The positioning of realist evaluation and synthesis alongside the widely accepted scientific method was seen as important to the acceptance of the approach. Nevertheless, an adaptation of 'The wheel of science' was required for realist strategies given the differing view of the term theory in realist research.

Theory underpins all the realist approaches and, as stated by Pawson, "the most fundamental realist claim about interventions, [is that] interventions are theories" (Pawson, 2006). Moreover, theories operate within contextual situations that affect the outcome of those interventions. Therefore, generalisable outcomes are not expected nor sought after. Instead, realist approaches seek to uncover in what circumstances, for whom and why interventions produce the outcomes and as such the wheel of science is adapted for realist work; see Figure 9.

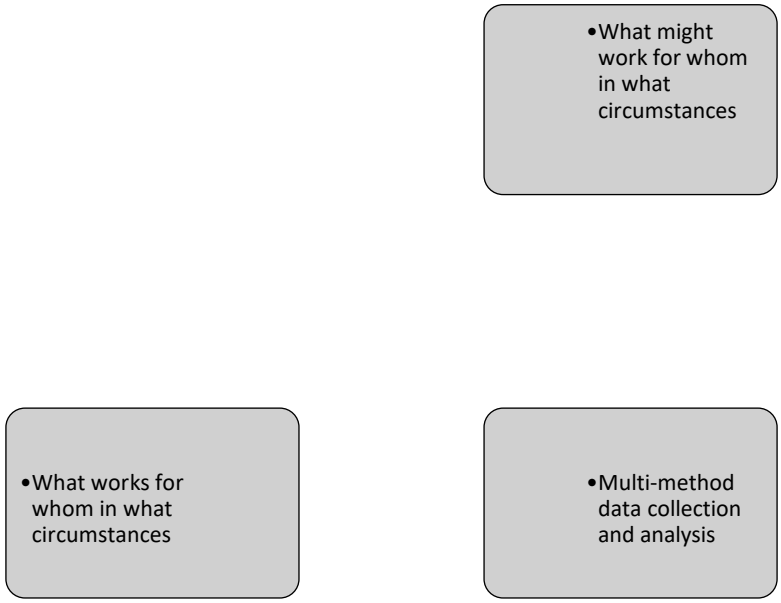

Figure 9: The realist evaluation cycle adapted from Pawson and Tilley (1997)

To those unfamiliar with realist research approaches, realist terminology presents a significant barrier to understanding and therefore what follows are detailed descriptions of realist terminology as used in this research.

Realist terminology

At first glance, the terminology used in realist research can be confusing, so much so, that the research can feel inaccessible. As a research paradigm, realist approaches are simply a way of thinking about a problem to provide an explanation of how, why and for whom an intervention or programme produces its effects. However, it is vital to understand the realist terminology so that the remainder of this research is accessible to the reader.

Context

Context is a general term with multiple definitions. Within realist research, contexts are anything separate to the intervention that affect outcomes through the enabling or disabling of mechanisms (Jagosh, 2018). Contexts can be related to the participants of the interventions, those who deliver it, or related to wider cultural, political or societal factors. Whilst contexts can effectively 'be' anything, for the purposes of realist research, the ones of interest are the ones that make a difference to the mechanisms and therefore the outcome.

It cannot be reiterated enough how important context is to the understanding of how programmes produce their effects, as only in specific contexts will mechanisms be enabled or disabled, generating the effects (Jagosh, 2018, Wong, 2018, Greenhalgh and Manzano, 2021). An understanding of the contexts in which the programme produces it effects as designed and those in which the effects are undesirable or unexpected is vital to the evaluation and understanding of the programme. It is important to remember that programmes themselves do not generate the effects, but it is the way in which participants interact and react to the programme that produces effects. This is drawn from the philosophical underpinnings of realist research that diverts away from successionist causation, or a positivist view, that X (cause) leads to Y (effect), towards generative causation that X (cause) leads to Y (effect) in Z (contexts) because of mechanisms enabled in specific contexts.

Contexts can be described as allowing mechanisms, which have causative potential, to affect the outcome (Pawson and Tilley, 1997). For example, gravity has the potential to make a ball drop to the floor when

dropped. Being situated on Earth (context^{1}) allows that potential mechanism to operate and the ball falls. On the other hand, being situated in space (context^{2}) means the ball does not fall. This example is purposefully simple to highlight the general definition, but contexts can be multiple and highly complex.

Coldwell (2018) reinforces that contexts are changing and dynamic in nature; an important issue bearing in mind that contexts could change over the course of an evaluation. Some interventions and resources can, indeed, may aim to alter the context itself to effect a change in the outcome. Likewise, Greenhalgh and Manzano (2021) point out that awareness of changing circumstances (contexts) is important to allow interventions to be successfully implemented. Adapting interventions considering the contexts into which the programme will be delivered is imperative to its success.

Mechanism: resources and responses

Mechanisms in realist research are the drivers of outcomes and give explanation to why and how interventions can generate their effects (Wong et al., 2017b). They are, by definition, hidden and not amenable to direct measurement but exist nevertheless at a deeper ontological level (Pawson and Tilley, 1997, Wong et al., 2017b, Westhorp, 2018). Whilst it may be possible to devise measurement tools or proxies for some of these mechanisms (Jagosh, 2020), you are not able to directly measure the mechanism itself. Mechanisms can be forces like gravity, emotions such as love or hate or cognitive processes such as motivation or understanding and learning (Westhorp, 2018).

There has been some debate and confusion over what constitutes a mechanism, in particular the disaggregation of mechanism into resources and reasoning/responses. Pawson and Tilley (1997) both describe mechanism resources as being "on offer" and provided by the programme but also state that resources reflect the "capacity" of the participants to put into practice what the intervention or programme provides for them. This has generated confusion over what is a mechanism in realist research.

Dalkin et al (2015) provided further illumination on this debate and advocated separating mechanism into resources and reasoning as shown in Figure 10. By encouraging researchers to "consider both concepts, [this] will contribute significantly to the explanatory endeavour of the realist researcher". The RAMESES II project (Wong et al., 2016, Wong et al., 2017b) further substantiated the position that mechanisms are "the interaction between programme resources and the way the participants interpret and respond to them" (Wong et al., 2017b). Potential confusion was foreseen with Dalkin et al's (2015) terminology of resources and reasoning given the scope of the research being reasoning development and therefore this research uses the terms mechanism resources and mechanism responses which has also been previously published (Wong et al., 2017b).

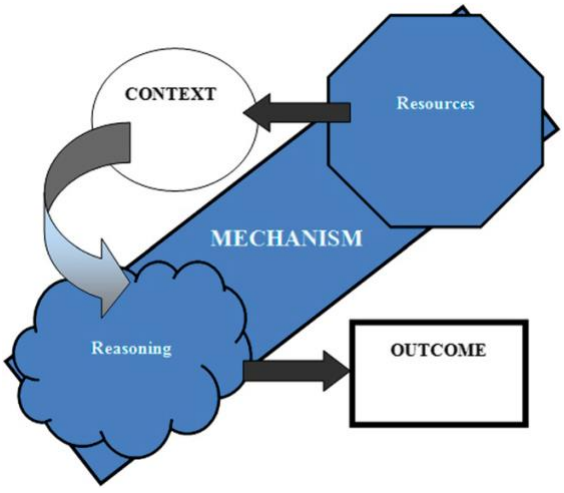

Figure 10: A context, mechanism, outcome framework. (Dalkin et al., 2015)

In this research, mechanisms are divided into the *resources* that are offered and delivered by the individual educational interventions and the *responses* of the students to those resources. Both the resource and response collectively form the mechanism, operating in context to produce the outcome of interest.

Outcomes

Outcomes for most interventions are the easiest to describe. Outcomes are the expected or unexpected results of the interventions. These may be directly measurable e.g. the rate of car crime after CCTV is installed (Tilley, 1993) or more difficult to measure if they occur over time e.g. learning. The outcome of interest in this research is the development of CR which, like anything complex to be learned, develops over a long period of time with multiple interacting components contributing to the development. This is not so easy to measure. It became clear during background literature searching that outcome measurements for CR studies often used diagnostic accuracy or accuracy of differential diagnosis. They might have also used self-reported outcome measurements or Likert scale outcomes of student satisfaction. It was the view of this researcher that these outcome measurements were not a true reflection of the process of CR, rather the outcome at a very proximal time point and this prompted further detailed thought of these issues pertinent to this research.

The challenge of measuring outcome

When outcomes take a longer time to develop or become apparent, measurement to determine whether an intervention has been effective or not

can be challenging. Sometimes, outcomes take years or even generations to develop and, in this case, we need some way of justifying the benefit of interventions even though the outcomes of interest are far removed from the interventions themselves. This is true for this research where CR takes years to develop and is constantly changing and developing even in expert clinicians.

Justification of the benefit of educational interventions to develop CR is challenging to provide for multiple reasons. Firstly, self-reported measures of learning via self-reported confidence, pre and post educational intervention are poor markers of learning (Liaw et al., 2012, Brinkman et al., 2015) and so it was a deliberate choice to not use these as markers of CR development in this research. Secondly, application of pre- and post-test assessments before and after an educational intervention may indicate the effectiveness of one intervention but not CR development overall as this occurs over longer periods of time. Thirdly, using OSCE or summative knowledge assessments enables potential determination of CR ability overall but does not allow outcomes to be linked back to individual educational interventions.

Finally, much of what drives CR development can be distilled to a concept which is both simple yet highly complex, learning. Learning is a mechanism as it exists in potential and activated forms and can be viewed as not being amenable to empirical data capture. This philosophical standpoint would advocate that all assessments are proxy equivalents, not just of outcome of interest but also of the mechanism of learning. In this view, assessments serve as a way of inferring that CR might have developed or be developing but do not measure the development of CR itself.

The lengthy development time and the challenges of measuring CR development raised issues of how effective CR development should be

measured. It is reasonable to assume that CR development is more likely in certain situations and evidence for this can be inferred using empirical data and corroborated by pre-existing educational theory. Many methods of developing CR are used as discussed in chapter 2, but the main aim of this research is to illuminate what is likely to work best in specific situations and for specific groups of people, in other words, acknowledging the role of context.

During the realist review, to be discussed in Chapter 4 and 5, the outcomes in this research were theorised as the impact on CR development, learning gains and effect of interventions on diagnostic accuracy. In later parts of the research, as the researchers own development occurred, the impact of single interventions on diagnostic accuracy as a single measurement of CR was conceptualised as being less important to the development of CR overall. In the findings from the realist evaluation therefore, the outcome measure was only the theorised effect of the intervention on learning and development of CR. Enough evidence has accrued over the years that further data regarding which educational interventions are effective to develop CR are not required. What is needed is to understand in what circumstances, for whom and why they are effective.

Context mechanism outcome configuration (CMOC)

Explanatory statements of how the intervention 'works' is operationalised by context (C), mechanism (M), outcome (O) configurations (CMOCs) (Pawson and Tilley, 1997) and collectively, CMOCs form a programme theory. CMOCs allow visualisation and analysis of the relationship between the context of the intervention and how the participants respond to the resources that the intervention provides them (mechanisms), to produce outcomes. Wong et al (2012) state that "contexts trigger mechanisms" and "mechanisms

generate outcomes" thus we see the importance of each of these components in the CMOCs. Figure 11 diagrammatically (Pawson and Tilley, 1997) illustrates how context, mechanism and outcome interact.

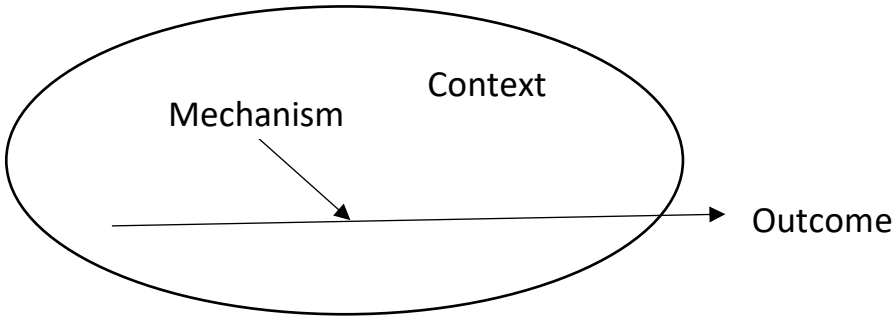

Figure 11: Diagrammatic illustration of context, mechanism and outcome adapted from Pawson (2006)

It has been suggested that it can be challenging to determine what constitutes a context or mechanism (Dalkin et al., 2015) and in fact certain constructs can be construed as context, mechanism or outcome dependent on the interventions being investigated. Consider motivation for example. This can be a context affecting how participants respond to interventions, it could be a response to an intervention and could also be an outcome of interest. Westhorp (2018) states "whatever enables or disables *the current mechanism of interest* operates as context for that mechanism". This provides a useful reminder when constructing CMOC's as whatever is termed a context, mechanism or outcome, the overall purpose is to provide an explanation of how, why, for whom and in which circumstances the intervention is generating outcomes or results. This is the most fundamental purpose of the CMOC, an explanatory statement.

Alternatives to the traditionally advocated CMOC have been suggested including ICAMO (Intervention-Context-Actor-Mechanism-Outcome) (Mukumbang et al., 2021) , CIMO (Context-Intervention-Mechanism-Outcome)

(Davies et al., 2018) and SCMO (Strategy-Context-Mechanism-Outcome) (De Weger et al., 2020). The benefits of utilizing a different heuristic for generative explanation depends on the nature of the research but as De Weger et al (2020) point out, any additional aspects of the CMOC statement should not detract from its overall explanatory nature. For this research, separation of mechanism into resource provided by the intervention and response of the participant was felt to be a useful alternative to the traditional CMOC (Dalkin et al., 2015). In this way this research may be stated to use MCMO (Mechanism Resource – Context - Mechanism Response - Outcome) configurations to provide statements of generative causation.

In the early stages of the work, it was sometimes challenging to disaggregate intervention components from mechanism resources. On reflection this particularly affected the realist review and is discussed in the more detail in Chapter 5. Throughout analysis, the researcher was cognisant of key realist axioms such as context being separate from the intervention and mechanisms being, by definition, hidden and not amenable to measurement, to try to avoid conflation of the mechanisms with intervention where possible.

Retroduction

It has been highlighted that mechanisms are a key part of the explanatory statement of generative causation and in fact mechanisms bring about outcomes (Pawson and Tilley, 1997). However, mechanisms are also hidden as they exist at a deeper level of reality that is not amenable to measurement (Bhaskar, 2008, Jagosh, 2020). Such vital pieces of evidence are uncovered through the process of retroduction.

Retroduction is central to the realist approach (Jagosh, 2020) and involves going backwards from the evidence to discover what has produced the observation or phenomenon in question, the underlying mechanisms that drive change. Retroduction is a form of inference (Mukumbang et al., 2021) alongside abduction, that enables theorising and as has been previously noted, theory and theorizing is key to any realist endeavour. Whilst abduction has been described as hunch driven or creative theorizing (Jagosh, 2020) and is required in realist work to start the process of thinking about what might be occurring, retroduction is inference from the available data to theorize the deeper mechanisms that produce the observable phenomenon (Jagosh, 2020, Mukumbang et al., 2021).

The process of retroduction has not been well published in the literature (Mukumbang et al., 2021) until more recently when some authors endeavoured to make their own retroductive thoughts more transparent in an attempt to make the operationalization of realist methods clearer and more open to the research community. Gilmore et al (2019) describe in detail their processes for data analysis and synthesis across two realist evaluations of community health interventions while Mukumbang et al (2021) reviewed realist reviews in an attempt to clarify how other realist researchers had described their retroductive thinking. Overall, how to approach retroductive theorising is not well described in the literature and there is a call for researchers to be more transparent in their realist research reportage.

The main challenge to making retroductive theorising transparent is for researchers to have a clear understanding of this process and what is involved. As Mukumbang et al (2021) hypothesize “We think that many realist researchers apply retroduction and abductive thinking while looking for the mechanism but are not aware of it”. On reflection towards the end of the PhD, in the early stages, through lack of understanding of the realist approach itself

and lack of published literature on how to describe retroductive thoughts, the retroductive process was not always clear to the researcher. It is only in the later stages of the work that retroduction and a deeper understanding of realist analysis, has become clear. Despite these challenges, the researcher's retroductive theorising will be made apparent to aid the readers understanding wherever possible during refinement of programme theory as described in Chapters 5 and 7.

The realist approach in this research

The initial phase of this research is a realist review, otherwise called a realist synthesis. This is a theory driven approach to collating primary data in a meaningful way to understand the mechanisms behind why interventions work or not and in what particular contexts this is true (Pawson, 2006). The process is iterative as opposed to the linear process of evidence collation by systematic review. This means that cyclical revisiting of previous steps in the process is seen as part of the natural course of the review. It is described in more detail in Chapters 4 and 5.

The next phase of this research is a realist evaluation. This realist evaluation utilises qualitative data although realist evaluation can use multiple methods (Pawson and Tilley, 1997). The principles of data analysis are the same as a realist review, except primary data are generated and analysed to revise the programme theory, in this case, as developed from the realist review. Chapters 6 and 7 describe the realist evaluation in this research in more detail.

Overall, the research aims to provide a more detailed explanation of the ways in which CR is developed in medical students using the approach shown in Figure 12.

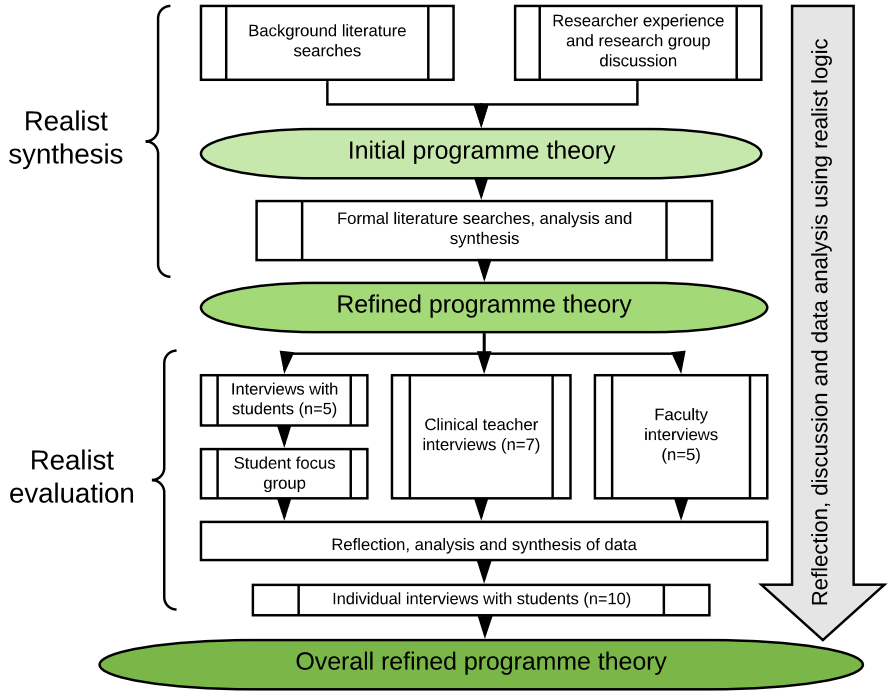

Figure 12: The proposed research process

Summary of chapter

This chapter has highlighted that CR development through education is viewed as a complex social intervention and utilising realist research methodology was justified. The underpinning philosophical assumptions of scientific realism were introduced. Realist research approaches are grounded in a realist philosophy of science and hold that interventions do not produce outcomes, rather participants responses vary in different contexts which describes how and why interventions 'work'. Realist terminology is used throughout this thesis. Contexts are anything separate to the intervention that affects outcomes

through the enabling or disabling of mechanisms. Mechanisms are both the resources offered by interventions, to which participants have a cognitive or emotional response which then drives outcome. Outcomes are the intended or unintended consequences of the intervention although in this study, the educational outcome of developing CR is challenging to measure. Explanatory statements: context, mechanism, outcome configurations (CMOCs) collectively form programme theory which provides an explanation for what is likely to work, for whom and in what circumstances, the realist research aim. Realist research can utilise multiple methods, but the data is interpreted through a realist logic. This research utilises realist review and realist evaluation and are presented in more detail in the subsequent chapters.

Chapter 4: A realist review of educational interventions to develop clinical reasoning in medical students – background and methods

Approach to the realist review

A realist review, or its synonymous term realist synthesis, is a research method for synthesis of primary data to answer the generic question of what works, for whom and in what circumstances (Wong et al., 2012). This contrasts with systematic review which primarily aim to answer the question 'what works best' (Pawson et al., 2005). A realist approach was considered suitable for this research for 2 reasons. Firstly, this research is concerned with establishing not just which educational interventions develop CR, but more vitally, an understanding of the circumstances and situations the outcomes are more likely. Secondly, it has been justified that education can be described as a complex social intervention (Craig et al., 2006, Pawson et al., 2004). A realist review is an approach to synthesising evidence on complex social interventions and therefore a realist approach was considered a suitable and the most beneficial approach to answering the research questions. The review was registered prospectively with PROSPERO, The international prospective register of systematic reviews (CRD42017072029) (Richmond et al., 2017).

To commence any realist enquiry, one must begin with a theory of how we expect a particular intervention to work. This is called an initial programme theory (IPT). This theory is then tested against the available evidence in order to refine, or refute, the theory (Pawson, 2006). This approach is recommended by the RAMESES group (Pawson et al., 2005, Wong et al., 2013b, Wong et al., 2013a) who describe stages in a realist review as detailed in Table 7.

Stage 1: Clarify the scope
Identifying the review question, refining the purpose of the review, key theories to be explored by way of relevant programme theories are described.
Stage 2: Search for evidence
Exploratory background searches and progressive focusing on key programme theories, followed by formal searching of the literature to test or refine theory following iterative approach with further searches to explore new theory areas as they emerge.
Stage 3: Appraise primary studies and extract data
Use judgment of rigour and relevance of the studies to the question under scrutiny and extract data onto bespoke data extraction forms from different studies.
Stage 4: Synthesize data and draw conclusions
Analyse and synthesise data to achieve explanatory, refined programme theory of what works, for whom and in what circumstances, focused to specific review question. Allow contradictory evidence to allow insights into the effect of context and present findings as a series of explanatory statements (CMOCs).
Stage 5: Disseminate, implement, and evaluate
Devise recommendations for practice, mindful of contexts and subsequent evaluation of the effects of changes to policy or interventions.

Table 7: The stages of conducting a realist review. Adapted from (Pawson et al., 2005)

Progressive focusing of reviews is advocated at various stages (Wong et al., 2013b) to ensure they are relevant and manageable given the available resources. A pragmatic approach to realist reviews is also recommended (Pawson, 2006) as it would be impossible to explore all the potential avenues of enquiry and reviewers need to be mindful of time, resources and research priorities. In research carried out for a PhD, a particularly pragmatic approach needs to be taken to keep the scope of the project manageable within the timeframe. Recently, Pawson (2019) stated on a realist discussion forum that PhD researchers need to "prioritise down to a very small number of programme/intervention theories" in order to achieve this task and that "you end up with a 'partial exploration of a partial set of ideas' about an intervention/ programme/transition. And that is the definition of a PhD". As such, progressive focusing to keep the research manageable was adopted throughout the process and this will be described where relevant.

The initial phases of the realist review were conducted during the researchers own learning and development in realist approaches. Thus, there are aspects, particularly during building of initial programme theory and clarifying the scope of the review, which may have been conducted differently if performed now. The following stages of the review are reported according to Pawson's stages of conducting a realist review (Pawson et al., 2005, Pawson, 2006). The RAMESES training material and reporting standards (Wong et al., 2013a, Wong et al., 2013b) were referred to at various points throughout the review to ensure consistency with published protocols of performing and reporting a realist review.

Stage 1: Clarifying the scope

Identify the review question and purpose of the review

This phase of a realist review can be time-consuming and a task which takes longer than anticipated and even beyond the mid-point of the review (Pawson, 2006). The intention of realist review is provision of explanation; uncovering not just what works but for who, in what circumstances and why (Wong et al., 2013b). Thus, as Pawson states, this is likely to open up a "whole range of potential sub-questions" (Pawson, 2006). Review questions therefore need to be prioritized (Pawson, 2006, Wong et al., 2013a) and "contained" (Wong et al., 2013b) according to priorities of the research team or commissioners/funders, according to the gaps in the literature or particular areas that need to be addressed or by taking a pragmatic approach. In this review, initial literature searches sought to identify the educational interventions or approaches that could develop reasoning in students of STEMM (Science, Technology, Engineering, Mathematics and Medicine) subjects as extending outside of the primary domain was recognized to be helpful in realist review (Wong et al., 2013b). The initial review question stated:

(i) What methods of educational instruction are used to develop or teach reasoning with respect to dual processing across undergraduate STEMM subjects, how effective are they and in what contexts do they work?

The review question was further revised though Stage 2 of the review (searching) as it became clearer that reasoning development was inextricably tied to domain specific knowledge, and as reasoning is not developed

separately to this, seeking literature from outside the subject domain, in this case medical education, was not thought to be adding weight to the findings.

The review questions that emerged were:

(i) What educational interventions are effective for developing analytical and non-analytical clinical reasoning ability amongst medical students?

(ii) When and why are they effective, for whom and in what circumstances?

Describe relevant key theories: Initial Programme Theory development

From Pawson's original description of articulating key theories to be explored and developing a formal model which is to be tested (Pawson, 2006), the terms Initial Programme Theory (IPT) (Wong et al., 2013b) or Initial Rough Programme Theory (IRPT) (Shearn et al., 2017) have evolved. There is both discrepancy in terminology used at this stage of the realist review and confusion at times over the development of this important, but vague concept. In many published realist studies, potentially due to limitations on word count, IPT development stage is often underreported. This causes confusion to the novice realist researcher about how to initiate and proceed with IPT development and potential failure to appreciate the scale of the task. Considering this, some authors have attempted to articulate in detail their development of IPT (Shearn et al., 2017, Flynn et al., 2020) to bridge the gap.

IPT development may uses a variety of sources such as scoping searches of the literature including policy papers and guidelines, discussions with experts, teachers or students (stakeholders) and from the researcher's experience (Wong et al., 2013b, Shearn et al., 2017). The IPT may develop from existing theory that have been used to explain a similar intervention or felt to be relevant by the researchers to the intervention in question (Shearn et al., 2017). As such the IPT may or may not be based upon empirical evidence but will be used as a lens to guide data extraction from empirical evidence, based upon what the researchers believe is likely to be happening to cause a particular intervention to work. This highlights again the importance of transparency and maintenance of an audit trail throughout the review so that decisions about the direction of the review can be clearly 'seen', potentially replicated and that researcher bias is not introduced (Pawson, 2006).

The IPT of how educational interventions might develop clinical reasoning in medical students is now presented. This IPT was developed with background literature searches, expert research team discussion and pre-existing educational theories.

Background literature searches

Pawson describes "mapping the territory" and "a period of hard reading" (Pawson, 2006) as being key elements of the first stage of the review in order that the researcher can devise the research question. Due to the iterative nature of realist research, it is not possible to exactly state in a linear sense, where background literature searches, discussion and review question creation feature. Each of these aspects is occurring in parallel and discoveries in one area effect changes in another. For example, building understanding in

the importance of domain specific knowledge led to changes in the review question.

Background searches and reading within this domain were initiated by articles selected by the supervisory team as being relevant and informal searches using Google Scholar to get a feel for the domain. This included the types of educational interventions that might be relevant, the terminology used by researchers in this field and an idea of what broadly might impact educational effectiveness. It was at this stage of the review that it was found determining educational effectiveness or outcome presented challenges as discussed in Chapter 3.

Scoping literature searches and background reading also highlighted that there are some contentious issues within the domain. Specifically, literature pertaining to cognitive biases within CR. Cognitive biases are a negative term applied when error results from unconscious cognitive processes when decision making or reasoning (Evans, 2010). The medical education literature suggests that these biases cannot be overcome by knowing about them alone and this led to developing more understanding of the importance of domain specific knowledge in CR as described in Chapters 1 and 2.

Expert research team discussions

Realist research is challenging, particularly for novices, but even within more experienced research teams, collaboration and discussion is a key element of development of an IPT (Wong et al., 2013b). Within the research supervisory team for this work, expertise was held within undergraduate, postgraduate and master's level medical education. Informal discussion within

the supervisory team helped shape the developing IPT as well as formal questioning as shown in Table 8.

Do you think teaching of clinical reasoning works? Why?
Do you have any feeling about particular circumstances it may work better than others?
Do you have any theory about what the best method for teaching clinical reasoning and why?

Table 8: Questions for the research team to aid IPT development

The discussions didn't generate new ideas but provided substantiation of the developing ideas from the literature and guided selection of the pertinent educational theories.

Integrating educational theories

Shearn et al (2017) note that abstract theories (grand or middle range theories) are often used to substantiate theory rather than build or develop IPT's. The pre-existing abstract theories noted here are educational theories that were used to understand how educational interventions develop CR. Specific educational theories that were drawn upon in IPT development included:

(i) Illness script theory
(ii) Cognitive Load theory
(iii) Experiential learning theory

(iv) Expertise theory

(v) Cognitive flexibility theory

(vi) Situativity theory

These theories have been discussed in detail in Chapter 2 and highlight the educational theories that support the conceptual model of CR development as used in this research.

Key components of the initial programme theory

IPTs take the form of various statements, theories or CMOCs (Shearn et al., 2017) that describe the possible theories to explain how an intervention is working. We combined researcher and supervisory team experience, scoping reviews of the literature and educational theories using CMOC statements. These are possible theories of why and how educational interventions that develop CR ability with respect to dual information processing in undergraduate students. The process of IPT development was iterative and reflection through writing, discussion and making sense of the data obtained from background literature and educational theories and research team discussion was required. Initially, it was not possible to construct complete CMOCs due to lack of data to understand the complete interaction between context, mechanism and outcome. With further reading, thought and discussion and immersion in the literature the following partial CMOC statements were developed (Table 9).

Expert teachers or practitioners (C) that can explain their thought processes (both intuitive and analytical) (Mresource) enable students to better understand (Mresponse) the use of both thought processes in clinical practice which may lead to improved diagnostic outcomes in students (O).	Students that have access (C) to education which encourages the use of both analytical and intuitive thought (Mresource), enables mistakes (Mresource), and allows students to practice this skill in a safe environment (Mresource) which makes them feel safe (Mresponse) which is important to learning (O).
In undergraduate medical students at any stage of their undergraduate training (C) encouraging them (Mresource) to think (Mresponse) fast or intuitively will lead to more accurate diagnosis (O) as promoting both types of thinking is the most important aspect of teaching dual process thinking in clinical reasoning.	In students with more subject specific knowledge (C) encouraging them (Mresource) to think fast, intuitively or use pattern recognition (Mresponse) will likely lead to more accurate diagnoses (O) as they have developed more knowledge and illness schemas to draw upon.
In students with more subject specific knowledge (C) encouragement (Mresource) to think analytically (Mresponse) leads to an overcautious approach (O) which is wasteful and doesn't improve patient outcomes.	In novice students with little domain specific knowledge (C) attempting to encourage (Mresource) them to think (Mresponse) fast or intuitively is likely to lead to failure in diagnosis/with the task (O) as they do not have adequate knowledge at this stage.
Expert teachers/clinicians (C) that are not able to explain (Mresource) their thought processes may leave students feeling confused (Mresponse) which leads to less understanding (O).	In novice students (C) encouraging (Mresource) them to reason (Mresponse) analytically is more likely to lead to diagnostic success (O).
In undergraduate students (C), explanation (Mresource) of the components of dual processing theory will lead to greater understanding (Mresponse) and allow students to use metacognition to determine the appropriateness of their current mode of thinking which decreases the chance of error (O).	Students who have positive coping strategies (C) when exposed to educational interventions such as simulation where making mistakes (Mresource) are part of learning, feel confident (Mresponse) and see mistakes are valuable to the learning process (Mresponse) which aids learning and reasoning development (O).
When students who have negative coping strategies (C) are involved in making mistakes (Mresource), they feel fearful (Mresponse), find the learning experience stressful (Mresponse) and this increased cognitive load and detracts from the learning goals (O).	

Table 9: Partial Initial Programme Theories

These initial statements were combined through searching for similar themes and ideas, and the following IPT's were developed which take the form of CMO statements show in Table 10.

Medical teacher knowledge
Medical teachers who have a good clinical and educational knowledge (C) are more likely to develop resources, interventions and explain their reasoning which promote dual process reasoning in students (Mresource). Students exposed to these interventions are more likely to engage and acquire developed illness scripts (Mresponse) which support dual process reasoning in their future careers (O).
Time and opportunities in the educational system
There are often insufficient opportunities or time for experience with real patients in the current undergraduate education system (C) which means that educational interventions which provide additional authentic experiences (Mresource) such as simulated environments are important to enable students to develop complete illness scripts (Mresponse) which will enable more accurate clinical reasoning in the future (O).
Students who lack domain specific clinical knowledge
When students who lack domain specific knowledge (C) observe expert consulting with patients (Mresource) may feel frustrated (Mresponse) that the answer has not come so easily to their minds. When these students (C) are exposed to interventions that promote analytical reasoning (Mresource), they feel reduced anxiety (Mresponse) which reduces cognitive load and aids learning (O).

Students with high domain specific clinical knowledge
If students who have high domain specific knowledge (C) are exposed to interventions that develop rapid thinking such as being encouraged to trust their first impressions (Mresource) they are more likely to have confidence (Mresponse) and be more accurate in their diagnoses and management plans (O). Overthinking the clinical problem (Mresource) doesn't improve diagnostic accuracy or clinical outcomes (O).
Students with positive and negative coping strategies
If students have positive coping strategies and feel they have available resources to deal with the situation (C), when they are engaged in simulated situations that aim to replicate the real clinical environment (Mresource) they will feel confident and pleased to have a chance to deal with the situation (Mresponse) which will increase the learning opportunities (O). If the student has a negative coping strategy or they feel they have insufficient resources (C), when exposed to the same intervention, they will feel fear and find the learning experience stressful (Mresponse) which will detract from potential learning and increase cognitive load (O).

Table 10: Initial Programme Theories (IPTs)

These initial theories may be incomplete and in need of refinement but acted as a lens to guide data extraction from the primary studies. In development of these IPTs, the terminology used within the medical education and CR literature became clearer which helped guide development of search terms and strategies which will be now discussed.

Stage 2: Search for evidence

This research was interested in CR development in medical students. However, as detailed in Stage One, it was thought initially to be favourable to extend the searches into other areas that might shed light on the answer to the research question. Therefore, original searches were planned for STEMM (Science, Technology, Engineering, Mathematics and Medicine) rather than just medical education. It became clear during the review that reasoning within each domain is highly dependent on knowledge within the domain rather than the ability to develop reasoning in isolation. Given the focus on undergraduate medical education, only articles from this domain were selected as relevant to the review.

Search terms

Search terms were deliberately kept broad to allow a full search of papers that may fulfil eligibility criteria as being more specific was found to be quite restrictive in terms of retrieved papers when compared to previous reviews (Schmidt and Mamede, 2015, Lambe et al., 2016). Search terms were developed for searches within STEMM subjects and specific to education within these areas. Within the databases searched, MeSH terms and descriptors were used where possible and plausible synonyms for relevant terms were derived from researcher experience and from background searches of the literature. The search terms used for OVID MEDLINE are shown in Table 11.

		AND	AND		AND
	exp Education/	exp Science/ed [Education]	exp Cognition/	dual process*.mp	Exp students/
OR	exp Teaching/	exp Technology/ ed [Education]	exp Thinking/	dual process theor*.mp.	Exp students, medical/
OR	exp Learning/	exp Engineering/ed [Education]	clinical reasoning.mp.	exp Metacognition/	Exp education, medical, undergraduate/
OR	Intervention*.mp	exp Mathematics/ ed [Education]	exp Decision Making/	exp Intuition/	Exp clinical clerkship/
OR	Activit*.mp	exp Education, Medical/	exp Problem Solving/	exp Heuristics/	Undergraduate.mp
OR	Instruction*.mp		exp Clinical Decision-Making/	analytic*.mp.	Exp Universities/ OR university education.mp
OR	Strateg*.mp		diagnostic reasoning.mp.	non analytic*.mp.	
OR			clinical problem solving.mp.	reasoning.mp.	

Notes: / - MeSH descriptor, .mp - searches for term in Title, Original Title, Abstract, Subject Heading, Name of Substance, and Registry Word fields, * - truncation, exp - exploded search

Table 11: Search terms as used for OVID MEDLINE

Search strategy

Databases searched included Medline, PsycINFO, ERIC (Education Resource Information Centre) & CINAHL (Cumulative Index to Nursing and Allied Health Literature). Initial searches were performed in May 2017.

Searching began from the year 2000 following the publication in 1999 of the seminal report 'To err is human,'(Kohn et al., 1999) which brought diagnostic error and clinical reasoning into the mainstream consciousness of the health care community and global public. Articles in English Language only were selected due to resource restrictions.

Search terms in CINAHL were specifically altered to include education across allied health professionals given the scope of this database rather than the general STEMM terms applied to other databases (nursing, midwifery, health sciences, occupational therapy, and pharmacy education).

Duplicates were removed and titles screened using reference management software (EndNote™). Title and abstract screening were performed. Abstract screening was performed when there was doubt about the relevance of an article based upon the title alone. Abstract screening was subject to assessment of relevance (see Appendix 1) and full text retrieved if the abstract suggested the paper would be useful towards theory building/refinement.

During full text review an educational intervention was defined as 'a teaching process or method for delivering knowledge or skills or information to a group or an individual' but experimental studies with important outcomes where the 'intervention' was instructions at the time of teaching e.g., think non-analytically or analytically, were also included.

Supplementary searches

Supplementary searches were performed in December 2017 to include terms found to be relevant following the first round of full text review. This approach is promoted in realist review to allow for emergent theories during the review to be explored (Wong et al., 2013a). These searches related to terms important in development of expertise and therefore type 1 reasoning. By this stage of the review, it was clear that the most relevant studies were with a domain of undergraduate medical education, so searches were only in this domain rather than STEMM subjects. An example of the repeat search is shown below which yielded 10 additional studies.

(i) *Exp education, medical, undergraduate/*

AND

(ii) *illness scripts.mp OR encapsulation.mp OR pattern recognition.mp OR reflection OR deliberate practice.mp OR naturalistic decision making.mp OR recognition primed decision making.mp*

AND

(iii) *clinical reasoning.mp OR exp decision making/ OR exp problem solving/*

Additionally, given the increasing understanding that subject specific knowledge was vital for clinical reasoning, a search for studies including learning strategies known to increase long term knowledge acquisition with respect to clinical reasoning development was performed (n=1). Finally, reference lists of included full texts were searched for relevant papers that could contribute to theory building (n=2).

The whole search strategy including supplementary searches and reasons for exclusion at full text review stage is shown in the PRISMA diagram in Figure 13.

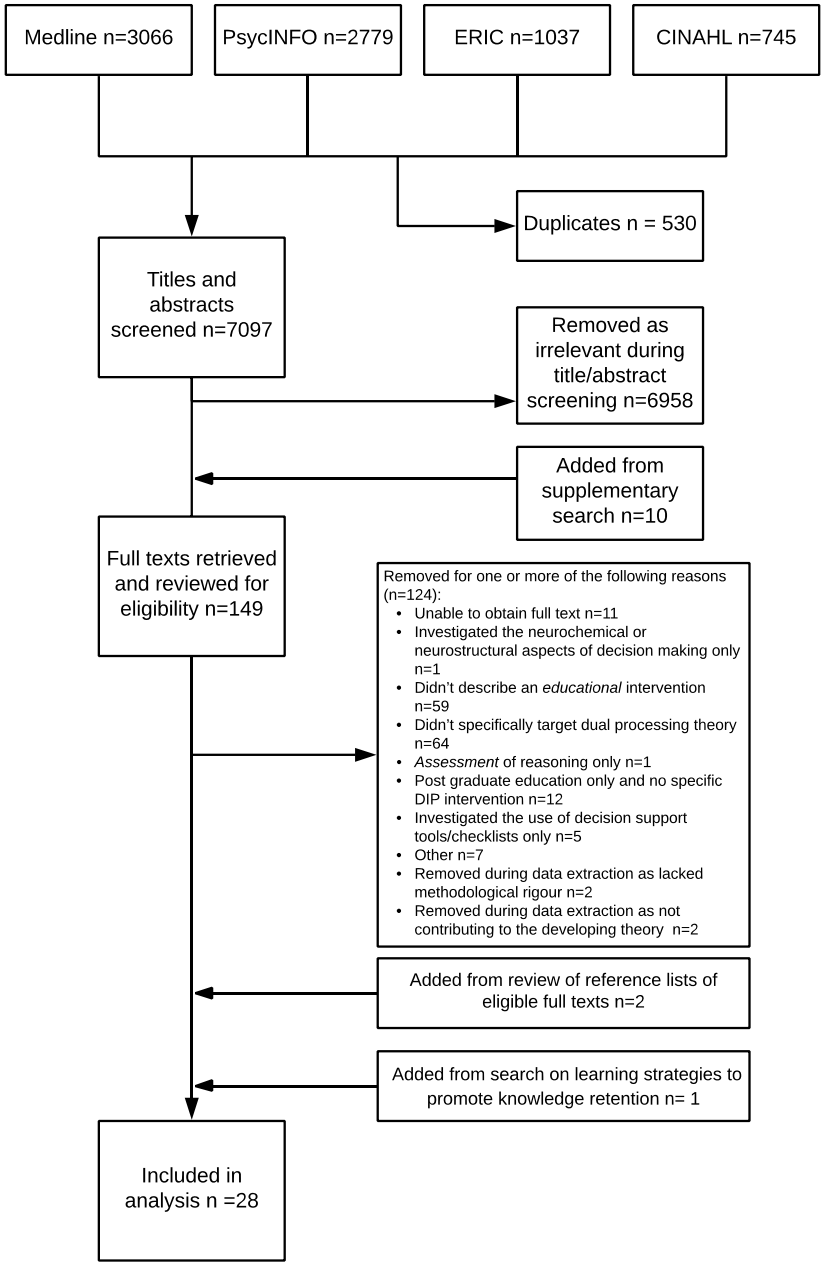

Figure 13: PRISMA diagram

Stage 3: Appraise studies and extract data

Appraisal of relevance and rigor was undertaken at various points throughout the review including at title and abstract screening and at full text review. Relevance was defined as the ability of the data to contribute to theory building or refinement (see appendix 1) and methodological rigour was determined by whether the methods used to generate the data were credible and trustworthy (Wong et al., 2016). Pawson et al (2004) suggest that quality appraisal in realist research cannot be determined by pre-existing checklists but the true worth of the selected study is in "*established in synthesis*". Studies individually may be both helpful to the refinement of theory but methodologically flawed in some way. The decision to include or exclude is based upon the overall use of the evidence to the study question (Pawson et al., 2004).

In determining the relevance of potential studies, several questions were asked including:

1. Does this study identify or describe a clear educational intervention or describe an intervention that has the potential to be used as an educational intervention?
2. Does this study include theoretical components of dual information processing theory or contribute to the theoretical development of reasoning underpinned by the DIP theory?
3. Does this study pertain to undergraduate education specifically? (Postgraduate studies could be included if there was a clear educational intervention that focused on DIP theory and CR development)

Data extraction

Data were extracted onto bespoke data extraction forms (see Appendix 2). To maintain an audit trail, data extraction forms were created for all reviewed full texts (n=149) and if excluded, reasons for this noted on the form. Context, mechanism and outcome configurations (CMOc's) were devised for all included full texts as well as narration about how the source contributed to theory building and understanding. Of the included full texts (n=28), initial data extraction including devising CMOCs was performed by the lead researcher with another member of the research team cross checking all data extraction forms for consistency. Where there were disagreements in coding, they were resolved by discussion amongst the research team.

Focusing the review

During data extraction, the evidence pertaining to contexts at the teacher and organisational levels were particularly challenging to uncover due to the information given in the published articles. It also became evident that contexts at the student level seemed to have the most impact on educational success. It was therefore decided, following the RAMESES guidance of progressing focusing of reviews (Wong et al., 2013b) that the individual student level contexts would be focused on for the remainder of the review. Contexts at the teacher and wider organisational levels were still felt to be important to CR development however and factors pertaining to the teacher and wider organisation were sought later in the research in the realist evaluation.

Summary of chapter

This chapter has described the background to the realist review and the development of the Initial Programme Theory (IPT) through combination of background literature searches, research group experience and existing educational theory. Search terms were developed based on the IPT and various databases searched systematically for articles that demonstrated rigor and relevance. Supplementary searches were conducted to include terms felt to be relevant after the first round and an additional search for interventions that promoted knowledge acquisition specifically to CR development. The review was progressively focused to keep the scope manageable, specifically looking at student level contexts rather than teacher and wider organisational levels. The IPT served as a guide to search for relevant data in the selected studies to refine the programme theory which is described in the next chapter.

Chapter 5: A realist review of educational interventions to develop clinical reasoning in medical students – results and discussion

Introduction

As introduced in Chapter 4, a realist review process is iterative but follows 5 stages. Stages 1-3 were described in Chapter 4, and Chapter 5 will describe stages 4 and 5 as shown in Table 12.

Stage 4: Synthesise data and draw conclusions
Analyse and synthesise data to achieve explanatory, refined programme theory of what works, for whom and in what circumstances, focused to specific review question. Allow contradictory evidence to allow insights into the effect of context and present findings as a series of explanatory statements (CMOCs).
Stage 5: Disseminate, implement and evaluate
Devise recommendations for practice mindful of contexts and subsequent evaluation of the effects of changes to policy or interventions.

Table 12: Stages 4 and 5 of a realist review adapted from Pawson 2005 (Pawson et al., 2005)

Stage 4 represents the main results of the review but also includes the approach to the analysis and synthesis of the data. Study characteristics are also included here.

Stage 4: Synthesise data and draw conclusions

Data synthesis

The aim of realist research is to provide an explanation through the building of CMOCs and the approach to data synthesis is an iterative process. Comparisons were made between studies and recurrent patterns of CMOCs were identified. As advised by Pawson et al. (2005), contradictory data was used to explore the potential differences in context that could account for the differing outcomes. Some studies particularly highlighted contexts whereas others gave more information about mechanisms. NVivo Version 12.1.0 (NVivo, QSR International Pty Ltd, Doncaster, Vic, Australia) used to store full texts and code contexts. Microsoft® Excel (Microsoft Corp., Redmond, WA, USA) was used compare data from different studies and to synthesise which contexts affected the mechanisms and outcomes.

Key contexts and mechanisms for determining effectiveness were eventually produced as outputs from the synthesis through this iterative process.

Results

Study characteristics

In total, 149 full texts were retrieved. Of these, 25 articles met the inclusion criteria and two more were added from reference list searching (Haig and Dozier, 2003). One was added from a subsequent search of learning strategies to promote knowledge retention bringing the total to 28. Details of the included papers are available in Appendix 3. Of the included papers, three were from the United Kingdom, eleven from Canada, three from the United States of America, two from Germany, three from the Netherlands and six from other countries.

A total of 23 studies were described in medical education, one was from veterinary education but with clear relevance to the development of CR (Bender and Danielson, 2011) and four involved psychology students (Ark et al., 2006, Ark et al., 2007, Eva et al., 2007, Evered et al., 2013). The total number of participants across the studies was 1495. Outcomes in the selected studies were heterogeneous with most defining diagnostic accuracy as the primary clinical reasoning endpoint (n = 13). Most included studies utilised quantitative methods.

Main findings: The Individual student

Orientation to the results

The selected studies identified key contexts for CR interventions at the individual level, with contexts at the teacher or the wider organisation level rarely discussed or theorised to be the main influencing context. Therefore, the results presented below predominantly focus on individual student level contexts. Five key contexts were identified:

1) Students with 'low knowledge,' low clinical domain-specific knowledge, or an inability to use knowledge in a reasoning situation.
2) Students with high clinical domain-specific knowledge.
3) Positive student coping strategies or appropriate level of self-confidence or self-efficacy.
4) Negative student coping strategies or lacking self-confidence or self-efficacy.
5) Students with different levels of knowledge within a group.

The interpretation of the evidence and contribution of specific papers to developing programme theories and CMOCs are referred to throughout this chapter. To aid with understanding, Appendix 3 contains the context/theory areas (1-5 as described above) that the included papers contributed to. These contexts had been identified through an iterative process of comparison between different studies and questioning what it was about a particular intervention that was causing an effect, or the circumstances where that effect may be different. Where a paper was found to provide data relevant to a specific context, this was noted and a further search for mechanisms through abductive and retroductive inference was performed, considering data across all included papers.

The findings of the realist review found multiple CMOC's which will be individually discussed and are presented as follows:

(i) Individual student context title.
(ii) A narrative explanation of the development of CMOC's with supporting evidence. Where possible, development from the initial programme theories is discussed.
(iii) An overall refined programme theory is stated.

Context 1: Low knowledge, low clinical domain specific knowledge or inability to use knowledge in a reasoning situation.

A student with low knowledge, low clinical domain specific knowledge or inability to use knowledge in a reasoning situation was the context which most affected whether CR interventions were likely to be effective. This is not unexpected given the research has focused on undergraduate education and medical students are novices in many clinical areas.

Within this context, initially the description of low knowledge was used but during development of the CMOCs, low knowledge alone was felt to be an insufficient description. In some studies, students were specifically selected for their low knowledge by including psychology students with no prior medical knowledge (Ark et al., 2006, Ark et al., 2007, Eva et al., 2007). Other studies specifically alluded to the notion that clinical domain knowledge was the most important by using cases in the studies that were less familiar or more familiar to the students (Chamberland et al., 2013). Some studies included students who could be theorised to potentially have lower knowledge, for example where students had failed examinations (Klamen and Williams, 2011). Included studies occasionally referred to students who may have had adequate knowledge within a clinical domain but for some reason they were unable to apply this knowledge in the reasoning situation (McGregor et al., 2012). All these elements of context were included as all had the potential to affect the way in which the educational interventions impacted the responses of the students and therefore outcome.

The IPT for this context stated:

When students who lack domain specific knowledge (C) observe expert consulting with patients (Mresource), they may feel frustrated (Mresponse) that the answer has not come so easily to their minds. When these students (C) are exposed to interventions that promote analytical reasoning (Mresource) they feel reduced anxiety (Mresponse) which reduces cognitive load and aids learning (O).

However, as the review progressed, this was found to be significantly oversimplistic and 8 separate CMOCs were developed from the data.

The overall findings for this context are shown in Figure 14. Following this visual representation of the results each separate CMOC is narratively described with the supporting evidence and the interpretation of this considering the initial programme theories. A total of 22 studies contributed to this context/theory area.

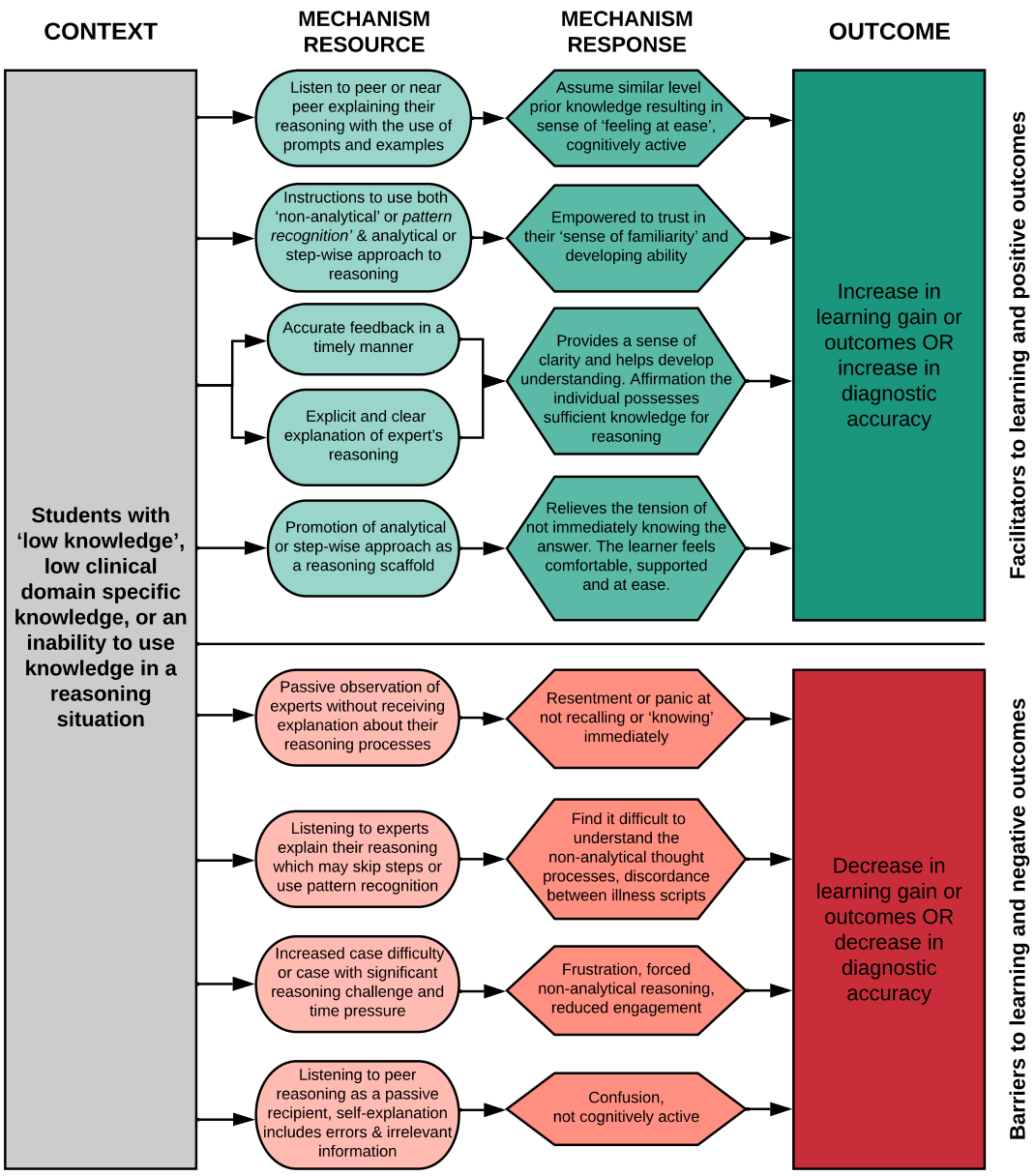

Figure 14: Visual representation of realist review results: Student with low knowledge, low clinical domain specific knowledge or inability to use knowledge in a reasoning situation.

CMOC 1a: Listen to near peers explaining their reasoning.

When students with 'low knowledge', low clinical domain specific knowledge or inability to use knowledge in the reasoning situation (C) listen to peers or near peers explaining their reasoning (Mresource) particularly with the use of prompts and examples (Mresource), there is a similar level of knowledge

between student and teacher (Mresponse), the student feels at ease (Mresponse) and is cognitively active (Mresponse) which results in an increase in learning gain or diagnostic accuracy (O).

Chamberland (Chamberland et al., 2011, Chamberland et al., 2013, Chamberland et al., 2015b, Chamberland et al., 2015a) has written widely on the value of self-explanation to the development of CR. Chamberland writes that there is additional value in students listening to the self-explanations of near peers (Chamberland et al., 2015a) but there may be limited benefit in listening to the explanations of peers or experts (Chamberland et al., 2015b). When students listen to their near peers' explanations of reasoning through a clinical case, the authors found the students' diagnostic performance on test cases improved, concluding that this approach is effective at improving diagnostic accuracy. In addition, when prompts to students own reasoning were added, this seemed to aid students solving cases later suggesting that the effect was more sustained, suggesting a longer-term educational benefit.

The authors suggested why they felt the explanations might be more useful to students when a similar effect was not seen when students listened to expert explanations:

"Junior residents represent near peers for medical clerks. Their clinical reasoning is close to, or cognitively congruent with, the students' own, which allows the latter to relate to it easily and to appreciate similarities and differences". (Chamberland et al., 2015a).

This familiarity and closeness of CR and a similar level of knowledge resulted in the students feeling at ease and were theorised as the mechanism responses enabling near peers' explanations to be more useful to students'

own CR development. In addition, the added prompts in this study ensured that students were cognitively active and considering their own reasoning whilst listening to the self-explanations of others.

In a study of a course with integrated cases designed to develop CR (Jacobson K, 2010), it was noted that listening to and observing peers explanation of their reasoning processes was useful to students. In this case the same mechanisms of cognitive congruence, knowledge level and feeling at ease were present. Peers had been noted in another study (Chamberland et al., 2015b) to cause confusion when their explanations were erroneous. However, if the explanations were accurate then a similar benefit to learning could be expected.

CMO 1b: Instructions to use both analytical and non-analytical reasoning.

When students with 'low knowledge', low clinical domain specific knowledge or inability to use knowledge in the reasoning situation (C) are given instructions to use both non-analytical reasoning or 'pattern recognition' AND analytical or a stepwise approach to reasoning (Mresource), students are empowered to trust in the sense of familiarity (Mresponse) and trust their developing ability (Mresponse) which results in an increase in learning gain or diagnostic accuracy (O).

Several studies in this research utilised absolute novices (psychology students) to investigate whether instruction to use both forms of reasoning would promote better diagnostic performance in a group with inherently low knowledge (Ark et al., 2006, Ark et al., 2007, Eva et al., 2007, Evered et al., 2013). In three of these studies (Ark et al., 2006, Ark et al., 2007, Eva et al.,

2007), instructions to use both forms of reasoning to solve clinical cases was found to have a beneficial effect and improved diagnostic accuracy.

Ark et al (2007) argued that "trainees [might be thought to] naturally and spontaneously adopt a combined approach to diagnostic reasoning" but found that in novices the instructions to think about the case both using non-analytical and analytical reasoning conferred a benefit compared to the group allowed to spontaneously reason through the cases:

"Instructions to utilise a combined reasoning strategy can improve performance above and beyond what can be expected in the absence of such instructions". (Ark et al., 2007).

Nendaz et al (2011) corroborated these findings in their study which examined the benefits of CR seminars. In this case, participants were experienced medical students in their final year of undergraduate training. The intervention group had tutors who encouraged the use of both types of reasoning and articulated their thought processes. For those cases where the students had good knowledge (the cases were relatively easy), instructions to use both types of reasoning conferred no benefit. However, for those difficult cases where the students had relatively lower clinical domain or case specific knowledge, the group which utilised both types of reasoning demonstrated superior diagnostic performance. They noted that:

"When students already have an experience with certain cases, a non-analytical, more intuitive approach may first take place, thus making a teaching approach using analytical steps less likely to influence the outcomes. On the other hand, such an intervention turned out more influential with harder, ill-

defined cases requiring a more elaborate analytical process". (Nendaz et al., 2011)

In contrast to these findings, Evered et al (2013) found that when novices were given the task of diagnosing cervical cytology slides using both types of reasoning it did not confer a diagnostic advantage compared to using non-analytical reasoning alone. This finding was unique to this study and potentially related to the visual nature of the diagnosis in this case. The notion of solely encouraging non-analytical reasoning in novices is contrary to all the available evidence of how reasoning develops and so was felt to be unhelpful to the developing theory.

Some educational interventions do not explicitly tell a student to reason with non-analytical or analytical reasoning but make this implicit by the questions asked of students. In the intervention by Pinnock et al (2012) students are required to initially consider diagnoses from limited information and then think through the case in more detail as it progresses. In this case both reasoning types are stimulated regardless of the level of student knowledge, and this also empowers students to trust in their developing abilities. Feedback and explanations are required to correct students' errors and aid understanding through filling knowledge gaps as discussed in CMO 1c.

CMO 1c: Accurate feedback in a timely manner OR receive an explicit and clear explanation of an expert's reasoning.

When students with 'low knowledge', low clinical domain specific knowledge or inability to use knowledge in the reasoning situation (C) receive accurate and timely feedback (Mresource) OR receive an explicit and clear

explanation of an experts reasoning (Mresource), this provides a sense of clarity, helps develop understanding (Mresponse) and an affirmation the individual possesses sufficient knowledge for reasoning (Mresponse) which results in an increase in learning gain or diagnostic accuracy (O).

Feedback is known widely to be a powerful and important educational intervention (Hattie J, 2007). This CMOC considered feedback with respect to CR development.

Bender and Danielson (2011) studied veterinary students exposed to an educational tool used to teach diagnostic reasoning and laboratory data interpretation, and which provided both immediate feedback and aligned their diagnoses and rationale to that of an expert clinician. The feedback being delivered immediately after the case had been solved was at the moment of "highest interest" and "highest engagement" which was theorised to impose germane cognitive load (Young et al., 2014), increasing learning from the case through understanding. The expert reasoning processes were revealed once the student had explained all aspects of the case and then students were encouraged to assess how well their responses aligned to that of the expert. This self-assessment was considered to provide students with affirmation that they do possess the necessary knowledge required for clinical reasoning. In this study, those students exposed to the intervention performed better than a group not exposed and preferred the educational approach to traditional paper-based methods.

In a similar educational intervention aimed at medical students, Pinnock et al (2012) designed a decision tree virtual patient software which enables students to "make decisions on investigations and management, with immediate feedback". This was specifically designed to reduce the lost

educational opportunities when feedback is not provided immediately after a decision, specifically an erroneous one, has been made. Whilst this intervention was delivered on a virtual platform, the design was to replicate clinical practice, including the expert feedback that students should receive if they undergo close supervision during real life clinical practice indicating that a similar educational effect would be expected outside of a virtual platform.

Kopp et al (2008) investigated the use of elaborated feedback informing them of the elements of knowledge used by experts when solving a case. This ensured that students understood why a particular response or diagnoses was incorrect. In this experimental study, students who had received elaborated feedback outperformed those who had feedback simply informing them of the correct answer without elaboration. This provides further evidence for the value of expert explanations and feedback to understanding, acquisition of knowledge and therefore in the learning required for CR development.

The finding of the particular benefit of immediate feedback to understanding and learning gains in CR development were corroborated by several studies including Klamen and Williams (2011) who investigated a multi-faceted educational intervention targeted at remediation of students who had failed an examination.

Interventions that enable explicit explanation of experts reasoning processes (Borleffs et al., 2003) illuminate the importance of ensuring that novices are able to understand these explanations. Experts can use rapid, non-analytical reasoning and, therefore, find explanation to students challenging. When the educational intervention is designed with novices in mind, and clinicians specifically aiming those explanations at students, this is likely to be more beneficial.

CMO 1d: Promotion of analytical or stepwise approach as a reasoning scaffold.

When students with 'low knowledge', low clinical domain specific knowledge or inability to use knowledge in the reasoning situation (C) are promoted to use analytical or a stepwise approach as a reasoning scaffold (Mresource), this relieves the tension of not immediately knowing the answer (Mresponse) and the learner feels comfortable, supported and at ease (Mresponse) which results in an increase in learning gain or diagnostic accuracy (O).

In a study of veterinary students (Bender and Danielson, 2011), students were novices and they often voiced frustration at not being able to understand the instantaneous diagnoses being made by their expert clinical mentors. The educational intervention was to alleviate this frustration by enforcing analytical reasoning by ensuring that all the clinical and laboratory findings were given an explanation. For this group of students, the tension of not knowing the answer was immediately reduced as this was not expected by the system. This resulted in the students feeling supported and eased into the diagnostic process.

The effect of listening to the self-explanations of others to CR development has previously been noted in CMO 1a. Using individual self-explanation as an intervention induces analytical reasoning and is beneficial to students, particularly with a lower clinical domain knowledge of a case (Chamberland et al., 2015b). This finding is supported by studies that encourage students to reflect in their reasoning, such as that by Mamede et al (2012) noting that medical students in year 2 of their studies performed better at a later test of diagnostic performance suggesting a longer term beneficial educational effect of this educational intervention.

In a similar approach to the study by Bender and Danielson (2011), Myung et al (2013) promoted analytical reasoning by encouraging students to complete a table of differential diagnoses and their rationale with compatible signs and symptoms. Students with lower knowledge had more accurate diagnoses using this approach, providing further evidence that this educational approach is beneficial. This effect is not seen in those students deemed to have higher knowledge however and is limited to lower clinical domain knowledge students (Nendaz et al., 2011, Myung et al., 2013). The rationale for this could be that higher knowledge students already have sufficiently developed illness scripts and therefore encouraging further analytical reasoning does not help them (see CMO 2a).

Coderre et al. (2010) found more evidence in support of this CMOC, where novice medical students solved clinical cases and were given opportunity to change their initial hypothesis (diagnosis) after more case information was revealed and therefore stimulated analytical reasoning. In this study, in those cases where the later information was concordant with the initial hypothesis students rarely changed their diagnosis, and their initial diagnoses were likely to be correct indicating employing analytical reasoning was not harmful to diagnosis. In those cases where the later information was discordant, students most often changed their diagnosis from incorrect to correct indicating that analytical reasoning was beneficial to diagnostic accuracy.

CMO 1e: Passive observation of experts without receiving explanation about their reasoning processes.

When students with 'low knowledge', low clinical domain specific knowledge or inability to use knowledge in the reasoning situation (C) passively

observe experts without receiving explanation about their reasoning processes (Mresource) they feel resentment or panic at not recalling or 'knowing' immediately (Mresponse), or a lack of understanding (Mresource) and a resultant decrease in learning gain or outcomes OR decrease in diagnostic accuracy (O).

Students very often observe experts in practice. Bender et al (2011) suggested that their students voiced resentment or panic when the answer didn't "pop into their minds immediately as it seemed to for their mentors". This concern prompted the design of their educational intervention.

Whilst students may observe others as an unspecified educational intervention, some authors have highlighted observation of experts as a specific educational tool with respect to CR development (Borleffs et al., 2003). In this description of an intervention called CR theatre, an explicit and accurate explanation of the doctor's reasoning processes was central to the effectiveness according to the authors. In fact, in these sessions the doctor consulted with the patient for one sixth of the time, during which time the students observed, and the remaining five sixths were dedicated to explanation and discussion about the case. Without the explanation, the educational effect would be lost as the students would only observe the doctor-patient interaction. When students have low clinical domain knowledge, the responses of lack of understanding, resentment and panic at not knowing are more likely.

Linn et al (2012) provide a practical guide for teachers to improve the development of students CR in the workplace. Teaching CR 'in the consulting room' is noted to be a valuable resource to CR development but limited by the "degree of automation that occurs when clinicians consult, which to the observing student is difficult to grasp and can be a barrier to learning". This is

especially noted to be true for novice learners, such as medical students, who have limited clinical experience. Linn et al (2012) also note that CR should not be viewed as a tacit part of the curriculum that students passively "pick up as they go along", highlighting again that observation of experts alone is educationally unhelpful for students with a low clinical domain knowledge.

CMO 1f: Listening to experts explain their reasoning which may skip steps or use pattern recognition.

When students with 'low knowledge', low clinical domain specific knowledge or inability to use knowledge in the reasoning situation (C) listen to experts explain their reasoning which may skip steps or use non-analytical reasoning or pattern recognition (Mresource) they find it difficult to understand the non-analytical thought processes and there is discordance between illness scripts (Mresponse) with a resultant decrease in learning gain OR decrease in diagnostic accuracy (O).

Linn et al (2012) describe the real life clinical environment where clinicians are trying to educate students whilst undertaking their clinical practice. They provide ideas to ensure that students gain more from these student-clinician encounters. It is noted that it can be challenging for clinical teachers to provide explanations to students, as their thought processes use automatic or non-analytical reasoning and as such a flowchart encouraging deconstruction of the clinical encounter is advised. This ensures the explanation received by the student utilises analytical reasoning and is therefore likely to be more understandable than the non-analytic CR process of the expert.

In agreement, Chamberland et al. (2015b) acknowledge that although experts have knowledge that undoubtedly novices could benefit from, they often reason automatically, meaning a novice may not be able to learn from, or even follow, an expert's reasoning process. Within their study, listening to expert explanation of cases didn't benefit students in terms of diagnostic accuracy, although the study was experimental and so the findings may not be relevant to real life educational activities. Students in this study were in their 3rd year but the cases all used clinical presentations of jaundice which was highlighted as being unfamiliar to students in the 3rd year, reinforcing that they were novices in this clinical domain.

CMO 1g: Increased case difficulty or case with significant reasoning challenge.

When students with 'low knowledge', low clinical domain specific knowledge or inability to use knowledge in the reasoning situation (C) are exposed to an increased case difficulty or a case with a significant reasoning challenge (Mresource) and a time pressure (Mresource) this results in frustration (Mresponse), forcing non-analytical reasoning (Mresponse), a reduction in engagement (Mresponse) and a decrease in learning gain or outcomes OR decrease in diagnostic accuracy (O).

Knowledge is specific to a clinical domain and specific cases and therefore varies from between and within those domains. Graafland (2014) investigated whether a serious game would enable learning within clinical decision making in surgery. This study was aimed at determining validity but also provided data on this developing CMOC. The study utilised participants of different grades, including medical students and found that those participants experienced significantly more frustration with the educational game than did experts or surgical trainees. The authors noted that the game difficulty was

potentially too high for some students suggesting that their knowledge relative to the cases was too low.

In the study by Graafland (2014), the nature of the game and a time limit intended to induce competition may also encourage non-analytical reasoning over analytical reasoning. In other studies where the case difficulty is higher (Jacobson et al., 2010, Nendaz et al., 2011), this was overcome by encouragement of analytical reasoning, perhaps in addition to non-analytical reasoning (Pinnock et al., 2012). When solely non-analytical reasoning is encouraged, even if unintentionally by way of a time limit, this is detrimental to students with an insufficient clinical domain knowledge.

CMO 1h: Listening to peer reasoning as a passive recipient or explanation includes errors.

When students with 'low knowledge', low clinical domain specific knowledge or inability to use knowledge in the reasoning situation (C) who listen to peer reasoning as a passive recipient (Mresource) or when that explanation includes errors (Mresource), this results in confusion (Mresponse) and learners not being cognitively active (Mresponse) leading to a decrease in learning gain or outcomes OR decrease in diagnostic accuracy (O).

Chamberland et al (2015b) have extensively researched the value of both self-explanations and the value of listening to the self-explanations of others. In other words, the explanations of the reasoning and their reasoning processes. This study investigated whether peers' or experts' self-explanations would be as beneficial to students. Overall, listening to the self-explanations of

others did not aid students' own CR as demonstrated by no change in their diagnostic accuracy scores on cases following the intervention.

Multiple reasons could be proposed to explain this finding. Peers' explanations often contained multiple, uncorrected errors plus irrelevant information. This was theorised to cause confusion and therefore not aid diagnostic accuracy. In addition, when listening to the reasoning processes of others, although the peers' explanations should be cognitively congruent and pitched at the correct level, without any prompts to ensure the student was cognitively active, students could listen passively, reducing the impact of the intervention.

Overall refined programme theory for Context 1.

When students have low knowledge, low domain-specific knowledge, or an inability to apply their knowledge in a reasoning situation (Context), there are multiple ways (Mechanism resource) in which educational interventions may develop their diagnostic accuracy or reasoning ability (Outcome). The context of low knowledge (C) combines with different resources to produce varying emotional and cognitive responses in the students (Mechanism response), which promote either positive or negative educational outcomes (O).

Context 2: Adequately high clinical domain specific knowledge.

In direct comparison with the first context of lower knowledge, the realist review also determined that adequately high clinical domain knowledge was a key context. In the early phases of the review, knowledge was arbitrarily

binary as either high or low. As the review progressed, this binary definition was seen as likely too simplistic but served the purpose of determining whether a student has low or adequately high knowledge for each case or teaching activity encountered. It is likely that the same student will differ in this context depending on the clinical domain and therefore would need to be individually assessed prior to each encounter.

The initial programme theory for this context stated:

> *If students who have high domain specific knowledge (C) are exposed to interventions that develop rapid thinking such as being encouraged to trust their first impressions (Mresource) they are more likely to have confidence (Mresponse) and be more accurate in their diagnoses and management plans (O). Overthinking the clinical problem (Mresource) doesn't improve diagnostic accuracy or clinical outcomes (O).*

Data gathered and interpreted through a realist lens during this review refined this IPT into 2 separate CMOCs as detailed below.

CMO 2a: Instructed to use analytical reasoning alone, especially with low difficulty cases OR teaching strategies that promote 'overthinking'.

When students with adequately high clinical domain knowledge (C) are instructed to use analytical reasoning alone, especially with low difficulty cases (Mresource) OR teaching strategies that promote 'overthinking' are utilised (Mresource), students are already able to trust 'sense of familiarity' and maintain diagnostic accuracy (Mresponse) and there is therefore no

improvement in diagnostic accuracy and a limited or no increase in learning gain or outcome (O).

Sherbino et al (2014) sought to determine whether learning about and employing strategies to overcome cognitive biases would reduce diagnostic error. These cognitive forcing strategies are akin to analytical reasoning and require the student to slow down and consider all the possibilities. The study found that employing cognitive forcing strategies to the cases did not aid diagnostic accuracy or reduce error. In those students with low clinical domain knowledge, previous studies have shown that encouraging analytical reasoning is beneficial but although the students in the study were selected as they were deemed to be novices, they were senior and final year. This, coupled with the authors' assertion that the cases might have been too easy (Sherbino et al., 2014), suggested that the participants had adequately high clinical domain knowledge relative to the cases used. This suggests that encouraging analytical reasoning in students with adequately high clinical domain knowledge does not aid their diagnostic accuracy. This was theorised to be due to these students already using non-analytical reasoning effectively and asking students to slow down and think through all the possibilities is therefore unhelpful.

Myung et al (2013) discovered that, overall, encouraging analytical reasoning through ensuring that students completed a table with differential diagnoses and compatible or incompatible findings, enhanced diagnostic accuracy. However, when looking at the specific cases, they found no difference between the groups asked to complete the table (analytical) compared with the control group with no specific mode of reasoning encouraged, when the cases were simple. In other words, for the cases where the students already had sufficient clinical domain knowledge, encouraging analytical reasoning conferred no advantage.

In agreement with these findings, Chamberland et al (2011), found that students' diagnostic performance improved when encouraged to use self-explanation as a form of analytical reasoning, but only when the less familiar cases of jaundice were used. When the cases were familiar (heart failure), the diagnostic performance was unchanged when analytical reasoning was encouraged. This again implying that those educational interventions that promote analytical reasoning in students with adequately high clinical domain knowledge are less likely to be effective in improving CR and diagnostic accuracy.

Nendaz et al (2011) highlighted a similar difference between those cases which the students were likely to have encountered and been familiar with compared to those more unfamiliar. The intervention of encouraging analytical reasoning and discussing the cases during seminar was more effective for those cases the students were unfamiliar with.

Chamberland et al (2013) explained that students use more biomedical knowledge when solving unfamiliar cases and produce more detailed explanatory statements, whereas more familiar cases result in fewer explanatory statements and more clinical knowledge. This study did not encourage a specific mode of reasoning but provided evidence that in students with familiarity and knowledge of the case their non-analytical reasoning processes are developing effectively and can be trusted. This was theorised to be a mechanism explaining why advocating for analytical reasoning in those students with sufficiently high clinical domain knowledge is ineffective at improving diagnostic accuracy.

The IPT stated that interventions that enabled high knowledge students to use and trust their non-analytical reasoning would develop confidence and

enable students to be more accurate in their diagnosis and management plans. However, the data available did not highlight any evidence to confirm this aspect of the theory area. This may have been because, in medical students, encouraging non-analytical reasoning alone is not felt to be safe given that medical students are often assumed to be novices.

CMO 2b: Reasoning processes of teachers identified and discussed.

When students with adequately high clinical domain knowledge (C) have discussion about an expert or teacher's reasoning processes (Mresource), they develop understanding about the process of clinical reasoning (Mresponse) which has a positive impact on learning outcomes and consolidates understanding about the process of clinical reasoning (O).).

Students of all levels of knowledge are likely to gain from listening to a detailed explanation of an expert's or teacher's reasoning process. If they have an adequately high clinical domain knowledge, they are more likely to be able to engage in discussion which was theorised to develop further understanding about the CR process.

Borleffs et al (2003) noted that discussion with the student audience was a vital part of the educational intervention in the "clinical reasoning theatre" and, whilst this intervention was beneficial to students who lack clinical experience, students with higher clinical domain knowledge are likely to benefit more as they are able to actively engage in discussions about the clinical case with the teaching doctors. In fact, students needing to ensure they focus on relevant knowledge was highlighted as being an important aspect of CR education implying that a student's level of clinical domain knowledge is

required to be sufficiently high to understand what is relevant to the clinical case and what is not.

Some authors (Linn et al., 2012, Pinnock et al., 2012) have highlighted that students often have adequate knowledge relative to the clinical case but applying it to specific patients can be challenging. As part of their recommendations to develop CR in the consultation room (Linn et al., 2012), prompting of discussion with questions that engage the student in thinking about why the clinician asked certain questions illuminates CR processes. This approach would work best with a student who had adequately high knowledge to develop understanding although it could be used with students of any knowledge level.

Finally, some authors have suggested ways that experts CR processes can be introduced to students virtually. Bloice et al. (2014) describe the annotations of electronic patient records that could be used to teach decision making to students. Experts reveal their thought processes to the students after they have worked through the case. The authors suggest that the cases should be prototypical cases similar to the cases that students would be expected to manage in their first medical jobs. This suggests that the cases should be not overly complex and that students should be expected to have sufficient knowledge about the case to be able to diagnose the problem but also to follow the experts' thought processes and rationale. With exposure to the rationale for these reasoning processes and decisions, it is expected that students gain understanding.

Overall refined programme theory for Context 2.

When students with high clinical domain-specific knowledge (C) are instructed to use analytical reasoning alone or this is promoted by ensuring they think through all aspects of the case (Mresource), they may feel frustrated (Mresponse) as they can rely on non-analytical reasoning (Mresponse) and still attain high diagnostic accuracy (O). When an expert's or teacher's reasoning processes or thoughts are explicitly revealed and discussed (Mresource) with students with sufficient domain-specific knowledge (C), this promotes understanding (Mresponse) into the reasoning process when diagnosing and managing patients (O) and a positive learning experience (O).

Context 3: Positive student coping strategies or appropriate level of self-confidence or self-efficacy.

The IPT for this context stated:

> *If students have positive coping strategies and feel they have available resources to deal with the situation (C), when they are engaged in simulated situations that aim to replicate the real clinical environment (Mresource) they will feel confident and pleased to have a chance to deal with the situation (Mresponse) which will increase the learning opportunities (O).*

Feelings of stress in simulated or real environments can be intrinsic or extrinsic to the task (Pottier et al., 2015). When those emotions are perceived by the individual as being necessary for performing the task they may enhance knowledge acquisition. Conversely, when emotions are perceived as peripheral to the task or distractors performance on task may be impaired. The ways individuals perceive emotional triggers as threats or a challenging opportunity

varies according to individuals' coping strategies when performing a task (LeBlanc, 2009). Tasks theorised to require a student to have effective coping strategies to negate the effect of the stress of the environment included those where CR tasks involve real patients or those simulated teaching environments where interaction with simulated patients is required.

McGregor et al (2012) investigated the benefit of a decision support tool, a seminar around the cognitive aspects of decision making and a simulated teaching session involving prioritisation and decision making. They gathered qualitative data from the students involved in the intervention. With particular emphasis on the simulated teaching session, some students found that they "felt stressed and out of their depth" whereas one student commented "I'm glad I had a chance to be exposed to that before I [was] put in the real situation". Similarly, in the qualitative evaluation of their virtual decision tree software, Pinnock et al. (2012), some students felt that the intervention 'put them on the spot to think' as it "seemed like a 'real case'". Given that the students were offered the same educational intervention but experienced it differently, this suggested that the students themselves were affecting their perception of the intervention.

Some students thrive in the stress of real-life situations, and this was theorised to be related to their ability to cope, their self-confidence and their self-efficacy beliefs; their belief in their own ability to be able to successfully perform the required task (Artino, 2012). In this case, those students with positive coping strategies and an appropriate level of self-confidence or self-efficacy calibrated to their previous performances would find simulated patient or real patient educational interventions beneficial to learning.

Experience, practice and making mistakes (Eva, 2009) are also vital to developing clinical reasoning ability and students. During development of this CMOC making and learning from mistakes was theorised as a vital educational activity that would be affected by students' coping strategies and levels of self-confidence. Simulated teaching interventions are designed to be safe environments for making and learning from mistakes since there is no direct impact on the patient of making that mistake. However, as shown by McGregor et al (2012), students find simulated environments stressful. Acute stress in the presence of positive coping strategies can aid task performance (LeBlanc, 2009) suggesting that a student's ability to perceive the task as useful, however challenging or stressful, is likely to have a beneficial educational effect as they will be able to focus on the task and potentially reduce extraneous cognitive load. The next section (Context 4) demonstrates the evidence that emerged for students with negative coping strategies or those lacking in self-confidence of self-efficacy beliefs.

Overall refined programme theory for Context 3.

When students with the ability to cope with the challenge of performing clinical reasoning (C) or students with an appropriate level of self-confidence or self-efficacy calibrated to previous clinical reasoning performance (C) are exposed to teaching that allow them to make mistakes (Mresource), real cases (Mresource) or those based on real-life scenarios (Mresource), they feel grateful for the learning experience (Mresponse), feel their decision making could have a real impact (Mresponse) and build understanding (Mresponse), which has a positive impact on learning (O) and develop more complete illness scripts and more accurate non-analytical reasoning (O).

Context 4: Poor student coping strategies or lacking self-confidence or self-efficacy.

The IPT for this context stated:

> *If the student has a negative coping strategy or they feel they have insufficient resources (C), when they are engaged in simulated situations that aim to replicate the real clinical environment (Mresource), they will feel fear and find the learning experience stressful (Mresponse) which will detract from potential learning and increase cognitive load (O).*

Bender and Danielson (2011) noted in their study of veterinary students that fear of making mistakes can increase cognitive load and subsequently detract from the learning goals. Their educational intervention was designed to reduce the fear or embarrassment of making mistakes as students could work through the problems in a virtual and safe environment. This negated the risk of making what they describe as "high stakes mistakes" which were determined as being mistakes that impact patient care. Being able to learn from mistakes in a psychologically safe environment is a cornerstone of simulation as a teaching method (Ziv et al., 2005) and has also been highlighted by other studies included in this review as an educational resource (Pinnock et al., 2012, Bloice et al., 2014). Simulation has been determined during this research as a key educational intervention in enabling students to engage with CR tasks and learn from their mistakes. Therefore, how students respond to this environment is key to determining outcomes.

As highlighted in Context 3 above, in the study by McGregor (2012), all students experienced the same simulated teaching session but experienced it

differently. Some students noted “It was stressful” or “I started to feel out of my depth”. In the context of students with lower self-confidence, self-efficacy or poor coping strategies, it was theorised that these students would have a higher extraneous cognitive load (Young et al., 2014) due to stress created by the educational environment which would detract from the learning goals. This outcome was not specifically investigated however in any of the studies included in the review.

To further evidence this theory, evidence was gathered from the literature regarding responses to stress. LeBlanc (2009) reviewed the evidence on the effect of acute stress on performance and highlighted that evidence regarding the effect of stress on performance are inconsistent. Stressors can be integral to the task which has been noted to optimise performance (LeBlanc, 2009, Pottier et al., 2015) or peripheral which may include distractions. Those stressors which increase focus and attention on a particular aspect of the task, for example a patient needing resuscitation, may have a positive effect on performance (Pottier et al., 2015) whereas distracting stressors tend to have a deleterious effect due to increase in extraneous cognitive load (Young et al., 2014).

In addition, it is highlighted that individual coping styles may affect perception of stress, with individuals predisposed to problem-based coping more able to manage the effect of the stress and those with avoidance coping styles trying to avoid or distance themselves from the situation (LeBlanc, 2009). One can imagine avoidance-based coping, or a lack of problem based coping strategies would have negative effects on a student’s ability to engage with educational interventions to develop CR if those tasks were perceived as stressful by the student. A further examination of different coping styles goes beyond the scope of this research but highlights the important effect of individual differences in perception of stress and therefore on performance.

The stress-performance curve is well documented and highlights that there is an optimum amount of stress during a task which will correlate with optimum performance. In development of CR, the complexity of interaction between individuals, their coping styles, perceptions of stress and other task factors such as knowledge and experience of the problem which contribute to the students' self-confidence and self-efficacy beliefs, suggest that the optimum performance curve is likely to be different for each student and this would vary according to the task require of them (Mendl, 1999).

Overall refined programme theory for Context 4.

When students with poor coping strategies or low self-confidence or self-efficacy beliefs calibrated to previous clinical reasoning performance (C), are exposed to simulated or real patient encounters (Mresources) or have made a mistake during learning (Mresource), they may experience fear (Mresponse), stress (Mresponse) or a pressure to perform (Mresponse). Consequently, cognitive load is increased (Mresponse) resulting in an increased chance of poor illness script development, faulty future non-analytical reasoning, and negative learning outcomes (O)

Context 5: Different levels of knowledge within a group.

Throughout the review, it was clear that knowledge was a key context in determining the effectiveness of many educational interventions to develop CR. Thus emerged the theory during the review that knowledge acquisition, whilst not directly impacting on CR development, was needed to improve engagement in other interventions. It was also clear that whilst educational

interventions impacted students individually, dependent on their pre-existing contexts, teaching is often delivered to students in groups with variable levels of knowledge. Even in these cases, certain educational interventions are beneficial to all, regardless of their pre-existing level of knowledge and therefore contribute to learning and future engagement in tasks that develop CR. The 2 educational interventions considered here include teaching approaches that aid knowledge acquisition and long-term knowledge retention, and feedback.

CMO 5a: Teaching approach designed around effective learning strategies to increase long-term knowledge retention.

When students of different levels of knowledge are taught within a group (C), a teaching approach designed around effective learning strategies to increase long-term knowledge retention (Mresource), enables engagement in other educational tasks that develop CR (Mresponse) and increases understanding about the process of clinical reasoning (Mresponse), which has a positive impact on learning outcomes and building or refinement of illness scripts (O).

Certain learning strategies are proven to be associated with more effective long term knowledge retention. These strategies have been widely published (Brown et al., 2014, Richmond et al., 2019, Sumeracki and Weinstein, 2017) and include the desirable difficulties (Brown et al., 2014). The strategies have been described in Chapter 2. These learning strategies can be applied to both students' self-directed learning and integrated into teaching. Their inclusion is theorised to improve long term knowledge retention which will aid students' engagement in many other educational activities to develop CR.

Whilst there are many studies investigating the effects of learning strategies, the effect of test enhanced learning on CR (Raupach et al., 2016) has been examined. Testing during learning incorporates the learning strategy of retrieval. This study found that the intervention of repeated testing was more effective that repeated case-based learning (control) as demonstrated superior performance in a CR test 9 months after the initial examination suggesting an effect of longer-term retention in the intervention group.

Ark et al (2007) investigated the benefit of guiding students in reasoning approach but also guidance to contrast between different, confusable diagnoses during ECG diagnosis. This study was undertaken with absolute novices (psychology students) but does demonstrate a medical example of how mixed practice (interleaving) enables contrast between different diagnoses which aids diagnostic ability. The positive impact of mixed practice to a medical domain was also seen by Hatala et al (2003) again in the domain of ECG diagnosis where medical students assigned to the contrastive (or mixed practice group) demonstrated superior diagnostic performance compared to those without.

Klamen and Williams (2011) incorporated the use of concept maps within their remediation intervention for students who had failed a clinical assessment. The remediation programme was multi-faceted and resulted in students achieving higher, and above the passing standard, post intervention in the clinical competency assessment. Relevant to this section was the incorporation of concept maps which contains many different learning strategies (dual coding, elaboration, retrieval and interleaving). The use of this technique was seen by the authors as important to aid knowledge acquisition which was theorised to improve clinical performance.

As these learning strategies are theorised to have a benefit to all students regardless of knowledge and could be incorporated into group teaching, a common occurrence during medical training, the context of varying levels of knowledge within a group was conceived to demonstrate the benefit of this educational intervention to all students. The mechanism response of engagement in other CR tasks was theorised due to the importance of knowledge in determining effectiveness of many other educational interventions to develop CR highlighted in this review.

CMO 5b: Comprehensive feedback received in timely manner following reasoning task.

When students of different levels of knowledge are taught within a group (C), comprehensive feedback received in a timely manner following the reasoning task (Mresource), increases understanding about the CR process (Mresponse), improves knowledge (Mresponse) and therefore increases engagement in CR tasks (Mresponse) which has a positive impact on learning outcomes and building or refinement of illness scripts (O).).

Several studies in the review noted the positive impact of feedback. Bender and Danielson (2011) and Pinnock et al (2012) specifically note that feedback is best provided immediately after the CR task as this is the point of highest engagement. The expert written feedback given in both studies is provided once the students give their answers which is built into the virtual educational interventions. The feedback can reinforce the students' answers and give them reassurance they have the knowledge if their answers are correct or can aid in refining and clarifying understanding if their answers differ from the expert.

Kopp et al (2008) included pre-worked examples where the cases contains errors and then elaborated feedback was given to the students. Not only does this method contain elaboration as a learning strategy and lower cognitive load associated with provided pre-worked examples (Schmidt and Mamede, 2015), it also provides students with immediate feedback and subsequent deeper understanding. Elaboration was defined as giving more than just the right or wrong answer but the reasons for this and the potential consequences of the decisions for the patient.

In the multi-faceted educational intervention to remediate students who had failed (Klamen and Williams, 2011) feedback was used as a tool to give detailed explanation of the student's performance and areas for improvement which enabled understanding about areas of weakness. CR performance was enhanced following this intervention, although feedback was only a component.

CMO 5c: Insufficient or incomplete feedback (including incorrect or erroneous in nature).

When students of different levels of knowledge are taught within a group (C) and feedback is insufficient, incomplete, or erroneous (Mresource) this results in confusion (Mresponse), reduced understanding about the CR process (Mresponse) and subsequent negative impact on learning outcomes (O).).

As a direct comparison with CMO 5b, feedback which is incomplete, inaccurate or contains errors was theorised to lead to confusion and therefore reduced understanding. Kopp et al (2008) utilised pre-worked examples where

the cases would contain either errors or not. Feedback was given as knowledge of the correct result alone and therefore could be classified as incomplete given that this method of feedback without explanation is educationally inferior. In this study, those students not given a complete explanation had significantly poorer diagnostic knowledge demonstrating reduced understanding.

In the study by Chamberland et al. (2015b), when students peers provided self-explanation of their reasoning processes and those explanations contained errors or irrelevant information, this led to confusion in students. The same mechanisms response was theorised to occur when feedback to the students was similarly erroneous or irrelevant.

Overall refined programme theory for Context 5.

When teaching students with different levels of pre-existing knowledge in a group (C), using strategies that promote knowledge retention (Mresource) will develop understanding and promote knowledge acquisition (Mresponse) necessary for CR, which leads to development of illness scripts (O) and further engagement (Mresource) in tasks that develop CR (O).

Providing accurate and timely feedback (Mresource) is an important component of developing reasoning skills in students with all levels of knowledge (C), to develop understanding (Mresponse) and generate plans for improvement. This is more likely to promote development of complete illness scripts (Mresponse) and successful non-analytical reasoning in the future (O). When feedback is incomplete or contains errors (Mresource) this can lead to confusion (Mresponse), reduced understanding (Mresponse) and have a negative impact on learning (O).

Overall results.

Figure 15 shows an overall visual representation of the results of the realist review demonstrating how the different student contexts interact and affect mechanism resources and responses and therefore outcomes.

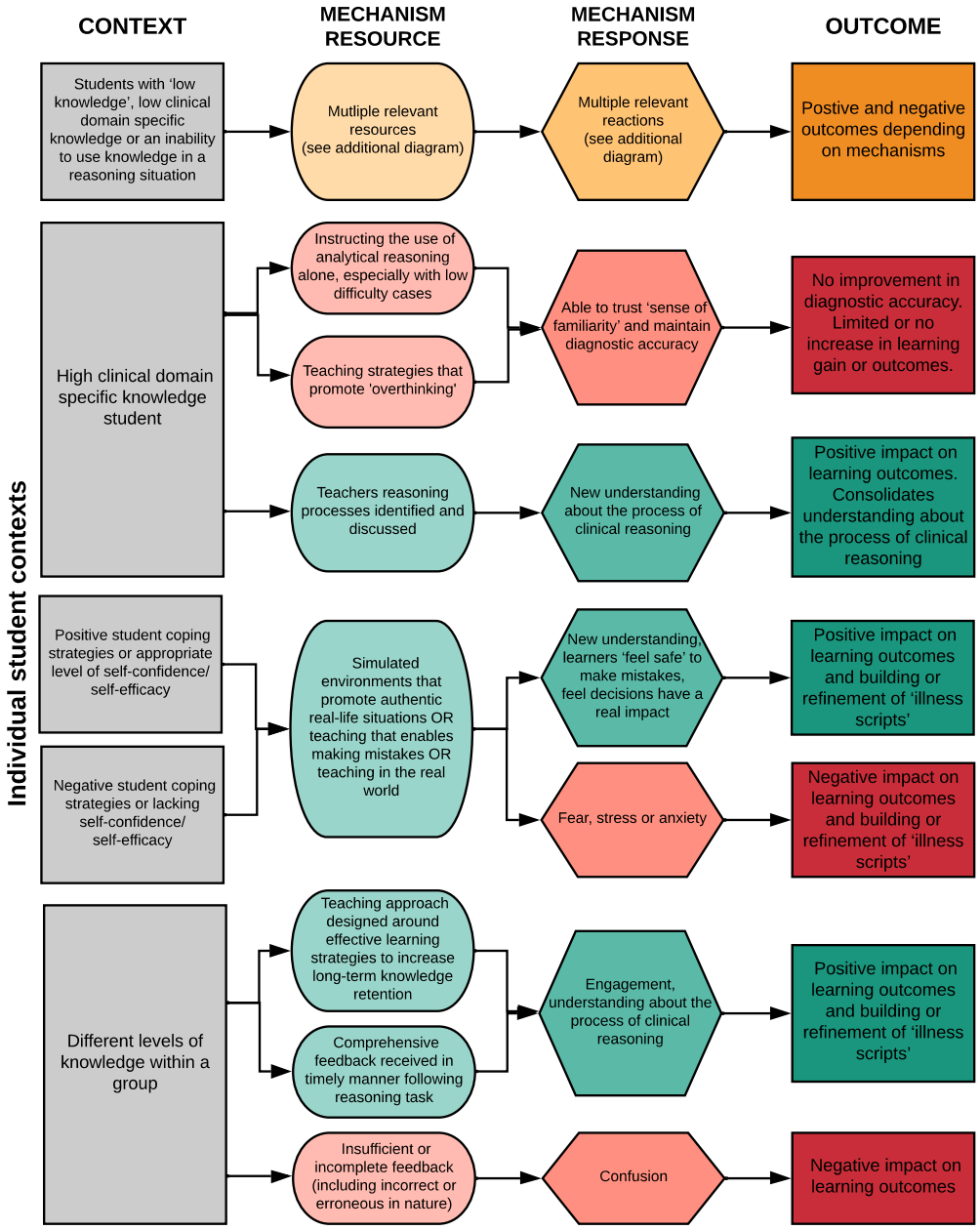

Figure 15: Visual representation of realist review results - individual student contexts

Other findings: Medical educators and the wider educational context.

From the IPT, contexts related to teachers or medical educators and the wider educational context and environment were presupposed to affect CR. During data extraction and synthesis, there was insufficient evidence these contexts were key in altering outcomes within the selected studies. Focus therefore was at the level of the individual student but given the complex nature of education to develop CR, it is likely that contexts at multiple levels will affect CR development. Contexts that were identified at the teacher and wider educational or organisational levels included:

Teacher contexts	**Wider educational/organisational contexts**
Motivation and experience	Access to a variety of patient presentations
Subject specific knowledge	Access to teaching
Knowledge of educational theory and instructional design	Available time for teaching
Training	

Table 13: Teacher and wider educational or organisational contexts.

Further analysis about how these contexts impact educational interventions was not performed at this stage of the research and therefore is not reported in this chapter. In the realist evaluation, their impact will be explored, and further detail provided.

Strengths and limitations

The main strength of this review is its realist nature which enabled thinking about the development of CR in students taking into consideration the contexts that affect the success of educational interventions. This enabled insight into the situations and groups of students in which certain interventions may be effective. This was the first review to evaluate educational interventions to develop CR from this unique methodological perspective.

One of the major limitations of the review was the lack of published literature that have contexts and mechanisms clearly described. This is not unexpected since most of the studies included in the review did not intend to consider the impact of context on outcome. However, this does mean that synthesis of the data was challenging. In addition, student level contexts were most described in the studies, although less on their effect on interventions with little information about potential mechanisms, particularly relating to the responses of the students. Throughout the synthesis process, retroduction and theorising were utilised to infer the information from the data available. Further work in this area is required to generate further evidence for the programme theories, particularly for mechanisms and contexts at other levels or pertaining to other important aspects of the educational process other than the individual student.

Widening the searches to include non-published studies and grey literature and accessing additional studies within and outside of medical education would have potentially enabled deeper understanding. It was not possible within the resource and time constraints of the PhD to perform multiple searches of the literature later. Studies that reported qualitative data or those richer in detail, aided development of the CMOCs more so than

quantitative studies but these were few within the selected studies. This is in part due to the type of research most often published in this area but also due to the researcher being a novice to realist research at the time and the research being conducted within the constraints of a PhD, and therefore more studies with richer detail were not sought.

Another criticism of the work is that the visual representations of the findings from the review are presented in a linear fashion. Whilst the aim of this was to aid understanding, particularly from a novice perspective, it perhaps generates a view that the process is simple, whereas it is complex. The visual representations also do not highlight the dynamic nature of context and therefore the way in which it might change over time, and they do not highlight that multiple contexts are interacting with multiple mechanisms at the same time for the same student which will affect overall outcome.

Lastly, the designations of context and mechanism resource are an aspect of this study which, upon reflection and deeper understanding, could be more accurately described. Some of the descriptions of mechanisms resources could be described as part of the educational intervention and a deeper exploration of the resources offered by the intervention could have been done. For example, the resource, increased case difficulty or cases with a significant reasoning challenge in the context of low clinical domain knowledge students, is part of the educational intervention rather than a mechanism resource.

Similarly, the context of varying levels of knowledge within a group was devised to highlight that the educational interventions can be effective in different students of different knowledge levels. On further reflection, the mechanism resource of feedback needs to be individualised to the student and the specific CR task or case to be the most effective. The mislabelling of items

in this part of the research was as a direct result of the researcher's inexperience within realist research and only became clearer upon writing the realist review chapter in this thesis. In the later aspects of the research, care was taken to ensure that contexts and mechanisms were categorised appropriately and that this best reflected the researcher's understanding and being faithful to the requirements of realist research.

Stage 5: Disseminate, implement and evaluate.

The findings of this realist review have been published (Richmond et al., 2020), providing partial understanding of the important factors to consider when designing and implementing educational interventions to develop CR in medical students.

Discussion and recommendations for practice

This realist review demonstrated that educational interventions seeking to develop effective analytical and non-analytical CR ability amongst undergraduate students do not work independently, but work inter-dependently with the individual, their pre-existing clinical domain-specific knowledge, and their ability to cope with the clinical reasoning task. Five key contexts were identified, and reports that the same educational intervention may 'work' across many contexts, but the effect is not the same across them all, especially amongst students with low knowledge states. Furthermore, this study provides more evidence that a 'one-size fits all' approach to delivering education is less effective and promotes an individualised approach taking the individual student contexts into account.

The ‘Matthew effect’ is well-described in the educational literature (Walberg and Tsai, 1983) and suggests that better pre-existing knowledge of an individual correlates with higher educational achievement. This review provides further evidence for this observation and suggests identifying the level of knowledge a student possesses for a given task or across a particular knowledge domain is necessary for predicting which educational interventions will be effective. Our findings are also corroborated by the expertise reversal effect (Kalyuga et al., 2003) where more experienced learners may not benefit, or indeed reverse learning gains, from those instructional techniques used for novices.

Often knowledge levels are assumed amongst students based on their year of study, having progressed through high-stakes assessments, or their accumulated total experience over a programme. Time spent on a course is a poor marker of competence (Frank et al., 2010) and this review suggests a given intervention may not have the same impact on all students, especially those with low knowledge states who need support the most. Furthermore, improving knowledge for CR has been highlighted as the most promising area to improve diagnostic accuracy and reduce error (Norman and Eva, 2010, Norman et al., 2017, Monteiro. S et al., 2020). This review supports this view, and the findings suggest improving knowledge structures and long-term knowledge retention for later recall is essential for the development of both confidence and competence in CR.

Although not the focus of the review, students with low knowledge featured heavily as targets for educational interventions to develop analytical and non-analytical CR ability. Effective teaching and learning strategies are particularly important amongst this group of learners as they provide the greatest challenge for clinical teachers. Retrieval practice, interleaving and spaced practice are examples of learning strategies, which induce ‘desirable

difficulties' amongst learners and demonstrate the promising outcomes for constructing knowledge and effective transfer into memory (Brown et al., 2014). These strategies promote long-term retention of knowledge by encouraging learners to revisit material over time, practice retrieving stored information in a variety of ways (such as quizzes or questioning) and mix different subjects together when studying rather than learning topics in silos (Richmond et al., 2019). Educators could use these strategies to increase knowledge retention prior to, or alongside experiences in simulated or real environments, so learners have sufficient knowledge not just for illness script formation and development, but also refinement after receiving feedback from teachers following performance on tasks.

Although the assertion that increasing knowledge alone is necessary for improving CR is still being debated (Croskerry, 2020a), the recommendation for more exposure to real patients in any environment for improving performance causes few objections. This study identified that exposure to real patients in practice or simulated environments was necessary for making 'safe mistakes' (Eva, 2009), although these experiences are impacted positively and negatively by students coping strategies and self-confidence. It is likely that simulated environments also provide a 'safe place' for students to also develop coping strategies prior to becoming doctors. Though the review set out to identify effective interventions for developing CR, the findings demonstrate that the self-management of emotions are also important in the development of CR ability.

Finally, educational interventions for CR have tended to favour approaches for developing analytical information processing (Bowen, 2006). However, the findings from this review suggest educational interventions for undergraduate students could do more to encourage students towards non-analytical reasoning when individuals have developed a sufficiently high level

of knowledge within the clinical domain. The challenge for educators is to identify baseline CR knowledge in order that appropriate educational intervention can be applied to individual students. There may be opportunities for further research to assess this knowledge in the moment using new educational technologies, such as adaptive e-learning (Fontaine et al., 2019). In the present, monitoring CR development over time and providing feedback about which approaches need further improvement at the level of the individual is down to decisions made by clinical teachers (Ribeiro and Moura, 2020). Furthermore, the challenge is identifying key behaviours known to affect self-confidence or self-efficacy when students undertake CR tasks (Cleary et al., 2016). Providing all this information for the educator in a way that is useful to them and useable for the learner is the most important first step in the process. Thereafter, both learner and teacher will hopefully be able to identify the most appropriate educational support for improving CR ability considering the contexts that will impact the educational outcome.

Summary of chapter

This review demonstrates that educational interventions seeking to develop effective analytical and non-analytical CR ability amongst undergraduate students do not work independently, but inter-dependently with the individual, their pre-existing clinical domain-specific knowledge, their self-confidence and self-efficacy beliefs and their ability to cope with the CR task. The review identified five contexts and reports that the same educational intervention may 'work' across many contexts, but the effect is not the same across them all, especially amongst students with low knowledge states.

The findings from this review were used as the starting point for the next phase of research to further refine and develop the programme theories

through the collection of primary data in a realist evaluation which is described and reported in Chapters 6 and 7.

Chapter 6: Realist evaluation: developing clinical reasoning in Nottingham: Introduction and methods

Introduction

The findings from the realist review highlighted various educational interventions and their resources that interact with student specific contexts and participants' responses to produce outcomes of interest. A limitation of the review was that included studies were not conducted with realist methodology and techniques in mind. This meant that data pertaining to potential mechanisms were lacking from the realist review. In addition, contexts were identified at the level of the individual student, with less focus on contexts at the teacher and organisational level. These contexts were mentioned in the realist review included studies but were not felt to be the most prominent contexts affecting outcomes and were therefore not prominent features of the review findings. However, researcher experience and initial programme theory suggested that all these contexts would affect CR development and so, further data for the contexts of interest and mechanisms were be sought by way of a realist evaluation of CR development at Nottingham Medical School.

A realist evaluation follows the same methodological principles described in Chapter 3 and as followed by the realist review as described in Chapters 4 and 5. However, in realist evaluation primary data is collected rather than synthesised. The general aim is to provide a refined overall programme theory comprised of CMOC statements. Throughout the realist evaluation, the RAMESES II reporting standards (Wong et al., 2016) and RAMESES II guidance for performing a realist evaluation (Wong et al., 2017a) were referred to and used as the standard of practice for performing this type of research. In addition, guidance from experts in realist evaluation was taken from the

RAMESES Jiscmail forum and from discussion with peers engaged in realist research at the University of Nottingham.

Methods of data collection in realist evaluation can be multiple and include both quantitative and qualitative methods but importantly, the methods chosen for data collection should be driven by the research question and theories that the researcher wishes to test (Pawson and Tilley, 1997). Towards the beginning of this research, it was initially felt to be beneficial to have an experimental study or quantitative data to increase the value of the findings. Experimental studies can be used alongside realist work and, dependent on the research question, can provide valuable outcome data. This positivist way of approaching research was familiar to the research team but with development of knowledge within realist research, it became clear this would not be useful to answer the research question for 2 reasons. Firstly, the experimental study would potentially limit for confounding variables and therefore not allow investigation of all the contexts affecting whether the educational intervention was likely to be effective. Secondly, the notion that a single educational intervention being able to develop CR is not consistent with the evidence that CR develops over a long period with multiple interacting educational activities and interventions having the most beneficial effect.

Following a period of reflection, it was decided that the most appropriate path for the research was to follow the development of theory using qualitative methods which has been well reported in realist evaluation (Wong et al., 2017a). The realist evaluation progresses the findings of the realist review with the main aim to further evidence and refine the programme theory. Overall, the research sought to answer the question:

- In what ways do educational interventions develop clinical reasoning ability among undergraduate medical students? What works for whom, in what circumstances and why?

Data pertaining to mechanisms was sought from the interviews with students to answer the question:

- How do individual factors/contexts affect medical students' reactions or responses when exposed to various educational situations to develop their CR ability?

The context of the study: Nottingham Medical school

The study was conducted at an English medical school at the University of Nottingham. During the 5-year undergraduate course students undertake 2 years of pre-clinical basic science learning before undertaking a 6-month BMedSci research degree. Students may also undertake an accelerated graduate entry course which includes 18 months of pre-clinical teaching. Students from both undergraduate and graduate-entry then commence 2 ½ years of clinical training at local education providers (LEPs) in the region including district and teaching hospitals, GP practices and various community settings. The students rotate around different clinical specialties during their clinical phase. Formative and summative assessments of performance occur throughout the course, but the main formal summative assessments occur at the end of the 3rd, 4^{th,} and 5th years (Clinical phases (CP) 1, 2 and 3 respectively). Medical students in the clinical phase of their medical undergraduate degree course were included in this research.

Ethics

Ethical approval was sought and granted by the University of Nottingham Faculty of Medicine and Health Sciences Research Ethics Committee (FMHS REC – reference 266-1903). Ethical approval for the amendment of performing interviews on Microsoft teams and gaining virtual consent via Microsoft forms was sought following the COVID-19 pandemic which prohibited face to face contact with participants. Details of the original ethics approval and later amendment can be found in Appendix 4.

Participant information sheets were designed for student participants and teacher/faculty participants separately and an example can be found in Appendix 5. Consent forms were designed and ethically approved. An example is shown in Appendix 7.

Reflexivity

Reflexivity in research is to deliberately consider the researcher's own position within the research and the impact this might have on the research conduct or interpretation of results (Berger, 2013). In positivist research, the researcher attempts to remain impartial to avoid bias on the results. However, in qualitative research, the interaction between researcher and participants and construction of data through social interaction means that this impartiality is not possible and, in fact, not favourable. Whilst realist approaches do not view data as simply constructed as it would be in some qualitative studies, the

evidence is still accrued through conversation (Wong et al., 2017a), thus the researcher is a central part of the evidence generated.

In realist research, the researchers' and team experiences alongside other methods such as stakeholder interviews or discussions and scoping reviews of the literature help to build ideas and theories of what is causing a particular intervention to work or not (Pawson, 2006). The researcher experience is a central point to creation of these initial programme theories and was used within this research.

The main researcher in this project was a medical doctor specializing in Obstetrics and Gynaecology and, at the time of the research, also engaged regularly in undergraduate teaching through their role as a clinical teaching fellow (CTF). In addition to this practical experience of undergraduate education, they also had obtained membership of the Academy of Medical Educators (AOME) and provided teaching to faculty at the University of Nottingham and local educators on the topic of CR. The research team consisted of practicing medical doctors, all of whom had an interest in medical education at either undergraduate, postgraduate or master's level. The combination of this experience meant that the researcher and the team were both well informed of the practical and theoretical basis of CR education and had awareness of the development of this skill within the clinical environment. This provided a potentially advantageous starting point in the research, but reflexivity warrants consideration of the potential deleterious consequences of the researcher's unique position.

Data analysis was occurring through the process of data collection and the researcher's experience enabled a more in depth exploration of emerging theories and ideas as they were more sensitized to certain aspects of the data

(Berger, 2013) . This was aided and recorded by the keeping of a reflective diary throughout the realist evaluation, an excerpt of which is shown in Appendix 8.

The main researcher was also a clinical teacher and therefore, during their undergraduate studies, some of the student participants had been taught by them. From a positive perspective, there had already been a relationship built between the researcher and the participant and a shared vocabulary which aided conversation. Conversely, for some students this 'closeness' of relationship may have meant they were less willing to share experiences, particularly negative ones. This was overcome to an extent by the consent process and reassurance that the process of research was both anonymised and would bear no impact on the student's future teaching experiences. Similarly, the clinical teacher participants and faculty members were known to the researcher from their teaching role. Again, this had helpful effects with a shared vocabulary and preformed relationship but may have impacted the researcher's ability to pursue further when the participants were more reluctant.

There were occasions in the research where the participants voiced concerns about their learning and development of CR. The researcher's position as an educator meant that on occasion time was spent with these students after the formal interview had finished to consider their concerns and where appropriate, educational advice was given to aid CR development.

Study design

The methods of primary data collection used in this realist evaluation included semi-structured realist interviews and a focus group. The following sections will consider these methods of data collection in more detail.

Realist interviews

Realist interviews are a well described method of data collection in realist evaluation (Manzano, 2016, Wong et al., 2017a) and describe an approach to gathering data driven by realist principles. In other words, the aim of the realist interview is to test, refine and refute theory (Pawson and Tilley, 1997) and therefore, in the same way as the realist review, the researcher must have some theory to test ahead of the interviews. In the case of this research, the programme theory derived from the realist review was the starting point of the realist interviews.

In qualitative interviews, the researcher aims to elucidate the participants experiences and views of the topic under investigation (Tavakol and Sandars, 2014), which is primarily driven by, and evidence constructed by the participant. In realist interviews the aim is to uncover the contexts in which certain interventions are effective or not and the reasons (mechanisms) for why and how the intervention produces its effects. This is directed by the researchers pre-existing ideas and theories (Wong et al., 2017a). Clearly the participants' experience of those interventions is an important part of discovering why, from whom and in what circumstances it is likely to work and so there are similarities between an interview conducted from a realist and a constructionist perspective. However, in realist research, evidence is seen as

not mere construction but a reflection of a real event (Manzano, 2016). Comparison between different respondents will often illuminate different contexts in which interventions are more or less likely to produce effects.

In realist interviews, the teacher-learner cycle is used to describe the approach to gathering data (Pawson and Tilley, 1997) whereby the researcher presents the participant with their theory and the participant provides their views and experiences to confirm, refute or refine that idea. In this way both the researcher and the participant act as both the teacher and learner (Manzano, 2016, Mukumbang et al., 2020) about the intervention or programme under investigation. In this research, theories to be tested and refined were derived from the realist review. As previously noted however, contexts relevant to the teacher and wider educational environment were not explored in detail in the realist review and this was an aim of the realist evaluation. Questions that were felt to be important to gather more evidence to refine theory was populated into an interview guide (see Appendix 6) and as such, although the interviews were conducted with refining theory in mind, their conduct was similar to a semi-structured qualitative interview (Tavakol and Sandars, 2014).

Focus groups

Focus groups within realist research have not been well described in the literature (Manzano, 2022), but have been widely accepted as a valid method of data collection within qualitative work more generally (Kitzinger, 1995). Focus groups have traditionally utilised a homogenous group of individuals with similar experience (Tavakol and Sandars, 2014) which promotes understanding of the ideas put forward for discussion (Kitzinger, 1995). Within realist research, focus groups inclusive of members with different experience and perspectives

has been recently advocated (Manzano, 2022). This heterogeneous group will allow discussion between different members of the group who belong to different "sub-groups" or have differing individual contexts (Manzano, 2022). The differences in individual contexts and the differing experiences of the programme or intervention under evaluation can be explored at a single time point and aid understanding about why outcomes occur in some situations and not others. The researcher can compare between different contexts from individual interviews but in a group interview, this comparison can be appreciated immediately. This does, however, require an excellent grasp of the potential theories explaining the programme and sufficient researcher experience in conducting focus groups where the data is to be interpreted through a realist lens. Focus groups as a research method also have limitations including domination by a few participants' voices which carries a risk of 'group-think'; a tendency for all to agree with each other. This may be particularly problematic in situations where the group is heterogeneous or there is a cultural hierarchy within the group leading to less contribution from more junior of submissive participants (MacDougall and Baum, 1997). Techniques have been described to avoid 'group-think' (MacDougall and Baum, 1997) when this is felt to be disadvantageous to the research but requires advance moderating skills and understanding from the researcher to allow elevation of all voices and therefore the comparison of experiences and contexts.

At the time of undertaking this research, the researcher's inexperience with realist methods and the paucity of published literature of focus groups within realist research contributed to the potential difficulties encountered. A focus group with medical students was planned, theorising that a focus group may encourage confidence in students, increasing their ability to speak up to the researcher about their experiences in comparison with individual interviews. Students in the focus group all had similar experiences of education at the same University, and so were relatively homogenous group. The focus group enabled a superficial account of potential educational interventions that

develop CR but was found to be challenging as a means of elucidating deep discussion. This was problematic when seeking data regarding mechanisms as it was challenging to deeply investigate individual participants views, a challenge that has been previously reported (Hollander, 2004). Following the conduct of one focus group, because of these concerns, further data was obtained through individual interviews only. The data from the focus group has been included in the research and have been interpreted respectively with a realist logic of analysis. A reflection on this approach and potential ways of making focus groups more valuable to this research is undertaken in chapter 8.

Theoretical sampling and recruitment

For realist research, the sampling process is similarly theory based (Wong et al., 2017a). Participants were selected for their ability to illuminate different aspects of the programme theory devised from the realist review. Following the realist review, the areas needing further research particularly included mechanism data and contextual data at the level of the teacher and wider organisation. By selecting participants from different perspectives deeper understanding of how CR is developed would be discovered.

Student participants had direct experience of receiving educational interventions that develop their own CR and an understanding about how they responded to certain interventions and why. It was hoped that student participants could illuminate their perception of student and teacher level contexts and, by articulating the way they responded to certain educational interventions, the researcher could infer mechanism responses to the educational resources.

Clinical teacher participants would have direct experiences of teaching and engaging with students. They may have had directly designed or implemented interventions that would develop students' CR ability. This experience would enable them to suggest the educational interventions that are most useful for certain groups of students and why they believe this is so, adding to context, mechanism, and outcome data. It was also hoped that this group of participants would share insight into organisational contexts that impact the success of CR interventions. Faculty participants have experience of designing courses or curriculums that develop CR. It was known that these participants would likely give a good overview of what should be happening to develop CR in students but potentially had less experience of what is happening in practice.

All students in their clinical phases were emailed to invite them to participate with interested students directly liaising with the researcher to arrange a mutually convenient time for an interview. Those students interested in participating in the focus group were given a specific time to attend. All clinical teaching fellows at Nottingham University Hospitals NHS Trust were invited to participate, again by email. Faculty members at the University of Nottingham were approached by direct email by the researcher. Participants were offered a £10 inconvenience allowance but not all participants accepted this reparation.

Data collection

It has been suggested that in order for emergent themes to be adequately assimilated and integrated into subsequent interviews, there are phases of interviews (Manzano, 2016). Initial interviews glean theory and later ones refine theory (Mukumbang et al., 2020) and as data analysis is ongoing

alongside data collection, the lines of questioning alter as further interviews take place. In most PhD projects the time constraints and resource restrictions mean this approach may not be possible. However, in this research, it was practically possible to have 2 cycles of data collection with a period of reflection and data analysis in between.

Cycles of data collection

The first cycle of data collection phase took place from June to August 2019 and after this time, saturation was felt to have been obtained in interviews of teachers and faculty. However, the data from students had not reached saturation as most of students who volunteered for participation were determined to be high performing students. Although this highlighted different contexts that were important, including a students' previous exposure and experience in a clinical environment, it was felt that the students who lacked prior clinical exposure and those who might have been defined as having low knowledge were under-represented. After a period of reflection and data analysis, a 2nd cycle of data collection was conducted in August 2020 to specifically explore student responses to interventions. 10 students were interviewed in this cycle of data collection.

Following the 1st phase of data collection, the COVID-19 pandemic affected much of undergraduate medical education. Whilst teaching did not cease entirely, the way in which students were taught changed, particularly for those students in the clinical phase of the course as teaching was delivered online. COVID-19 impact was not specifically questioned about in the 2nd round of interviews, but the researcher was aware that it had altered some students' experiences. Likewise, there were some educational activities important for developing CR but not considered thus far, including virtual teaching

experiences, which were considered in these interviews. As previously stated, the COVID-19 pandemic dictated a change in ethical approval in order that interviews could be conducted using Microsoft Teams and that consent could be taken using Microsoft Forms.

The interviews and the focus group were audio-recorded and transcribed using a university approved external provider. The researcher listened to all the interviews and the focus group audio and made reflective notes about the relevance to developing theories. This approach allowed a more in-depth knowledge of the data which aided analysis. Interview questions for the 2nd cycle of interviews were amended according to the emerging themes and reflection on the 1st cycle of data and further amended as new theories emerged (see Appendix 8 for an example of the researcher's reflective diary). All audio files, transcripts and reflective notes were uploaded to NVivo qualitative data management software for coding.

Data analysis and presentation of results

Initial coding was to context, mechanism and outcome separately as parent and child nodes in NVivo. However, the connections between the separate elements of the CMOC were difficult to visualise using this approach, a problem reported by others engaged in realist research (Dalkin et al., 2020). It is important in a realist approach to not list separate contexts, mechanisms and outcomes but to connect the separate pieces of data together as an explanatory statement (the CMOC). Because of the inability to do this through this approach, an alternative was sought.

Following discussion with peers also engaged in realist research it was felt to be most effective to use NVivo to keep track of data sources but to code to whole theory areas rather than individual components of the CMOC. To achieve this, the researcher further reviewed the audio-recordings and transcripts and made reflective notes on the data. This process highlighted multiple interventions that were developing reasoning and 5 key mechanism resources provided by these interventions were identified. Through a process of reflection and aided by writing connections between contexts and mechanisms several CMOCs were developed encompassing the 5 key resources.

Using NVivo to manage the data, evidence from the transcripts and reflections were coded to these CMOCs. Where further emerging theory areas were noted, an annotation was made to the transcript or reflection. Adaptations to the CMOCs were made where evidence arising from data was conflicting with or refuting the original theory. This was particularly important to identify where data from different sources pertaining to the same intervention, suggested a different educational effect. In these cases, different contextual data was explored to explain the disparity in outcomes.

Data analysis is ongoing alongside data collection in realist evaluation although final analysis of data did not occur until after the data collection was completed. Retroductive thinking, as introduced in Chapter 3 was required to infer the deeper mechanisms that could be driving the educational effects of the interventions. Chapter 7 will describe in more detail the retroductive thought processes used during the development and refinement of the various CMOCs.

Summary of chapter

This chapter has detailed the methods used in the realist evaluation. Realist interviews have been well described in realist research and served as the main method of data collection alongside a focus group. Quantitative data was not utilised in this research due to the challenges in measuring CR and relating educational outcomes to specific interventions. Participants were sampled purposively due to their experience with various aspects of the educational interventions to develop CR and therefore theoretical ability to refine the programme theory. Data was collected over 2 cycles with analysis alongside and a period of reflection on the findings in between. NVivo and Microsoft Excel were used to store and manage data. The results are discussed alongside how the data contributed to programme theory development in chapter 7.

Chapter 7: Realist evaluation: developing clinical reasoning in Nottingham: Results

Introduction

This chapter unites the findings from the realist review with empirical data gathered as part of the realist evaluation to generate the refined programme theories that are the main product of this research.

Participant demographics

Participants were students in their clinical phases at the University of Nottingham, clinical teaching fellows at Nottingham University NHS Trust or faculty members at the University of Nottingham, all of whom also had educational roles as part of their routine clinical practice. The clinical phases at the University of Nottingham include students in year 3, 4 and 5 of a 4-year (Graduate Entry) or 5-year degree.

In total 27 interviews and 1 focus group with 4 students (total 31 participants) were conducted as shown in Table 14.

PARTICIPANTS	1ST ROUND	2ND ROUND
MEDICAL STUDENTS	5	10
CLINICAL TEACHING FELLOWS	7	-
FACULTY MEMBERS	5	-
STUDENT FOCUS GROUP (1)	4	-
TOTAL	21	10

Table 14: Numbers of participants in interviews and focus group

Of the student participants, their course type and year of study is shown in Tables 15 and 16.

	A100 (UNDERGRAD ENTRY)	GEM (GRAD ENTRY)
MEDICAL STUDENT COURSE	10	5

Table 15: Medical student course type - undergraduate (A100) or graduate entry (GEM)

	3RD/CP1	4TH/CP2	5TH/CP3
YEAR/CLINICAL PHASE	1	4	10

Table 16: Medical student year of training and clinical phase at time of participation

The faculty and clinical teacher participants had various roles. The faculty participants had roles in the planning and running of the medical school curriculum and individual courses pertaining to their clinical specialty. All the faculty participants also had clinical teacher roles and so evidence from these

interviews often focused on their roles as faculty as well as their roles as clinical teachers. Clinical teacher participants were all clinical teaching fellows (CTFs) at Nottingham University Hospitals NHS Trust, specifically focusing on clinical education of students as they rotated through different specialty attachments. Some CTFs had a background of being doctors, others were allied health professionals such as physiotherapists or pharmacists. Description of the specific roles and responsibilities of the individual participants may enable their identification. Therefore, to protect anonymity of participants, further description of the roles and responsibilities of each individual participant will not be provided.

Coding of the results

Throughout the results chapter, reference is made to the empirical qualitative evidence captured during interviews and the focus group. Table 17 shows the shorthand descriptors for each of the participants where direct quotes or shortened excerpts of data are given in the results.

Participant	Descriptor	Example
Student participants	Student, participant number, interview or focus group	Student_01_interview OR Student_01_focusgroup
Clinical teacher participants	Clinical teacher and participant number	Teacher_01
Faculty participants	Faculty and participant number	Faculty_01

Table 17: Participant coding system

Coding to direct quotes can be challenging in realist research since emerging ideas can develop over several paragraphs of the same interview or indeed over several different interviews. As such coding can be direct, indirect or more holistic (Gilmore et al., 2019). As part of the analysis process, the researcher reflected on the interviews and focus groups and evidence directly taken from these reflections is referred to in the text as shown in Table 18. An excerpt from the researcher's reflective diary can be found in Appendix 8.

Participant	**Descriptor**	**Example**
Student participant reflections	Student, participant number, researcher reflection	Student_01_reflection
Clinical teacher participants reflections	Clinical teacher, participant number, researcher reflection	Teacher_01_reflection
Faculty participants reflections	Faculty, participant number, researcher reflection	Faculty_01_reflection
Multiple sources reflections	No specific participant, evidence from multiple sources, reflection	Researcher_reflection

Table 18: Coding system where researcher reflections are used as evidence.

The outcome measures in the realist evaluation

In most circumstances any educational intervention or activity doesn't negatively impact CR development or have a negative impact on learning, but the educational effect might be lessened or reduced when certain contextual factors do not facilitate a positive learning or developmental experience. The outcome measures for the realist review were theorised to have a positive or negative impact on learning. With further researcher development and learning, the outcomes described at the realist evaluation are either a positive effect on learning or CR development or a lessened or reduced effect on learning on CR development.

Mechanism resources development

Whilst the results of the realist review are presented by context, once further exploration of the key theory areas took place during the empirical data collection, it became clearer that multiple contexts affected individual educational interventions. It is possible to present realist research data in multiple ways. In this research presenting data in a way useful to the clinical educator was felt to be important. Medical education research can often feel disconnected from the practice of medical education. This may be because medical education is often delivered by clinicians who are not familiar with research in the social sciences and as such the research feels inaccessible to them. A part of this research was to bridge the gap between findings from medical education research and practice. As such, the findings are presented by first discussing the educational resources and the educational interventions that provide these resources, followed by more in-depth narrative of the contexts and how these impact the educational outcome. This approach provides a perspective and understanding of how these activities herald

different outcomes in certain situations or for specific groups of students. It is anticipated that clinicians or educators will be able to change parts of practice in each individual teaching and learning encounter, such that cumulatively educational value is enhanced overall for all students.

The resources offered by various educational interventions were viewed as part of the mechanism, that is, the educational intervention offers a resource to which the students respond. As detailed in Chapter 3, mechanisms are not amenable to direct measurement or observation as they exist at a deeper ontological level (Bhaskar, 2008). This means mechanisms, both resource and response need to be retroductively theorised, also as discussed in Chapter 3 (Jagosh, 2020, Mukumbang et al., 2021).

The main way in which the mechanism resources were theorised and developed was by the researcher considering various educational interventions and questioning the ways in which these interventions were developing CR ability. These resources were then considered for their similarities before grouping into the 5 main resources for ease of understanding of the results. The educational interventions that were thought to develop CR were derived from the research team experience and the results of the realist review and included those shown in Table 19:

Being encouraged to use analytical reasoning including self-explanation	Teaching about the clinical reasoning process
Being encouraged to use non-analytical reasoning including time pressure	Real experiences on wards and clinical areas
Observation of experts reasoning	Explanation of expert thought process
Observation of peers/near-peers	Explanation of peer thought process
Feedback of CR ability – what specific feedback do they get	Explanation of near peer thought process e.g., CTF's
General strategies to improve knowledge	Simulated patient encounters
Practicing with virtual patients and cases	Case discussions with educators
Worked cases/serial cue cases and case-led teaching sessions	Practicing clinical reasoning with real patients

Table 19: Educational interventions thought to be able to develop Clinical Reasoning

Some of these educational interventions offer more than one educational activity in order that CR is developed. For example, in considering simulated patient encounters, students can practice CR with simulated patients, have discussion with educators, observe their peers, be instructed to use analytical or non-analytical reasoning, and learn something new about that clinical case. Each of these interventions or activities provides the student with a resource. The mechanism resources conceptualised in this research are shown in Table 20 and the educational interventions that contribute to them are discussed in the following results sections.

Mechanism – resources
Participation in Clinical Reasoning tasks
Learning from mistakes
Learning about the Clinical Reasoning process
Encouragement of analytical and non-analytical reasoning
Knowledge acquisition, retention and recall

Table 20: 5 Mechanism resources offered by educational interventions to develop CR

Orientation to the presentation of the results

The following sections detail the main results of the research. They are presented as follows:

1) A title of the educational mechanism resource.
2) Descriptions of the different educational interventions that offer this resource.
3) Subheadings with different contexts that interact with and impact this resource.
4) A narrative description of the development of the CMOC drawing on the empirical evidence using quotes, excerpts and researcher reflections on the data.
5) Revised CMOC for each key context.

Overall results

Figure 16 shows a visual representation of the refined programme theory. Subsequent sections will describe its development through a narrative of the data interpretation.

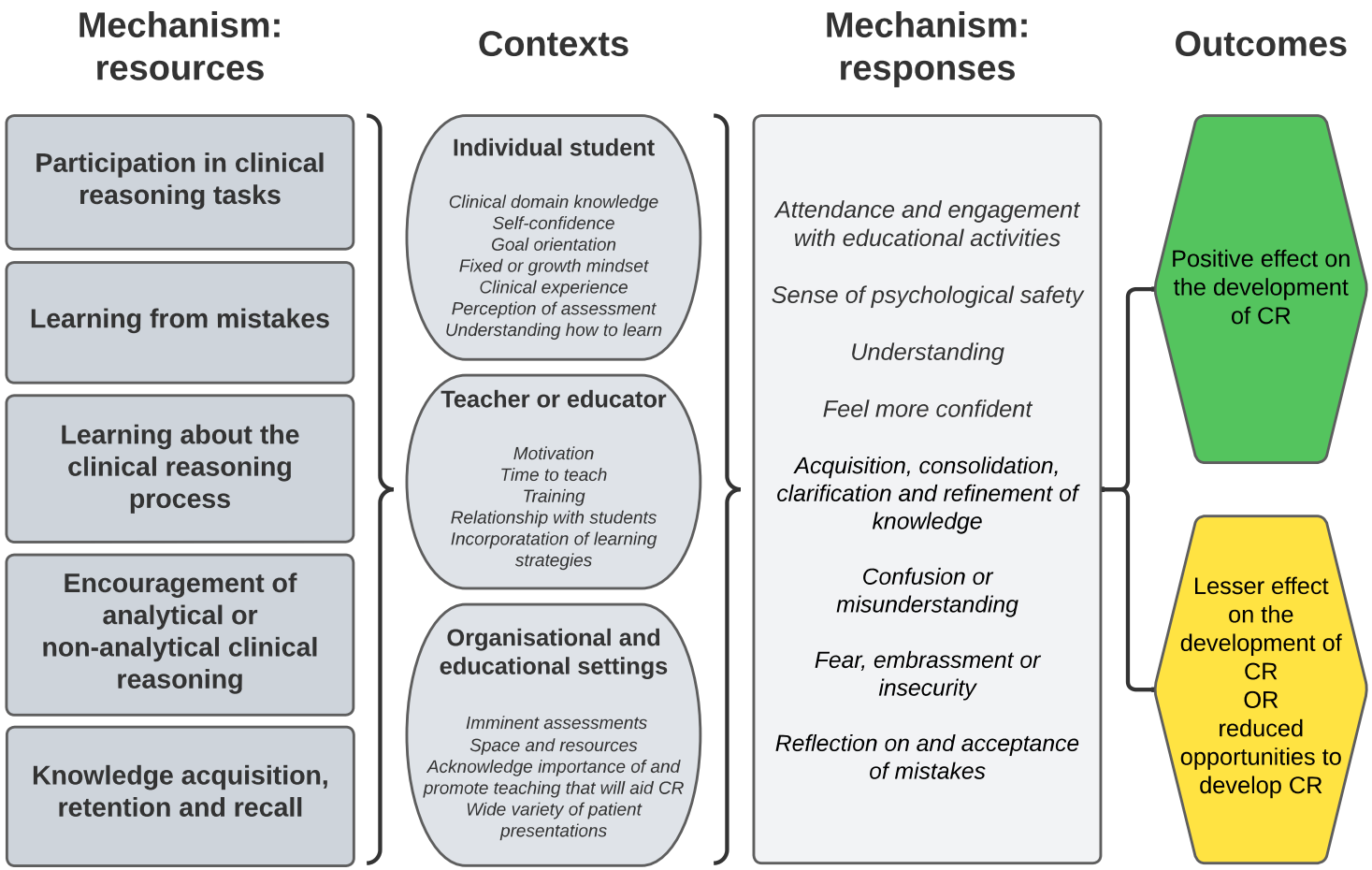

Figure 16: Overall visual representation of the refined programme theory

Participation in clinical reasoning tasks.

There are multiple activities that provide opportunity for students to participate in CR tasks which is classified as a resource offered by educational interventions. These may include students interacting with patients in clinical environments such as in a ward or clinic setting, interactions in simulated environments or interactions with virtual patients. Participation in CR tasks can also be achieved by observation in certain circumstances as will be described later. In clinical placements most of these opportunities are students being able to participate in CR tasks in the real clinical environment.

There are different elements of CR tasks and students may get opportunity to participate in one or many of these. Daniel et al (2019) provided a working definition of the components of clinical reasoning as discussed in Chapter 1, Table 1. Participation in CR tasks could be within any one of these components. Early years students may demonstrate only information gathering but with increasing student experience and knowledge, expectation is that students start to move through the different CR components and progress onto management of the patient's problem. The idea that participation in CR tasks is important and develops with increasing experience and knowledge was highlighted by several faculty participants.

> "I see medical teaching that you have to be doing it and if it's an apprenticeship, so the more you see the more you do, hopefully the better you will become." Faculty_02

> "…by the time you get to CP2 and 3 [4th and 5th year] you're really expecting them to do a lot of the formulation of where you would go

next with investigations and why and maybe outlining a management plan.” Faculty_03

“…a student moving on through will have seen a number of cases, will recognise something and will start to have a much more focused-directed, sort of potentially hypothesis testing approach to it.” Faculty_04

Given that participation in CR tasks is viewed as both important and its development is expected throughout undergraduate training, this resource is key for CR development.

Student adequate clinical domain knowledge.

The results of the realist review placed student knowledge as a key context of whether educational interventions to develop CR are successful. The CMOCs developed from the realist review found high knowledge was a key element to positive learning with respect to CR but did not consider the interaction with participation in CR tasks specifically. It was hypothesized that this context would have a positive effect when students participated in CR tasks and this view was also affirmed by many of the participants.

“The ones who've already done some of the activities before coming in, it helps to consolidate what they’ve got and then also clear their doubts. So, their knowledge basis is larger than the ones who haven't done the activity. And then it gives them an opportunity to interact with more

confidence, for example, when they're sitting in clinics or talking to nurses and talking to patients." Faculty_01

Knowledge and confidence were felt to be both independent but also dependent contexts. For example, in the quote by Faculty_01 above, adequate knowledge gave students opportunity to interact with more confidence and confidence in the clinical environment enables more engagement in CR tasks. This was theorised as a cycle of knowledge, self-confidence and engagement which perpetuates learning and development as shown in Figure 17.

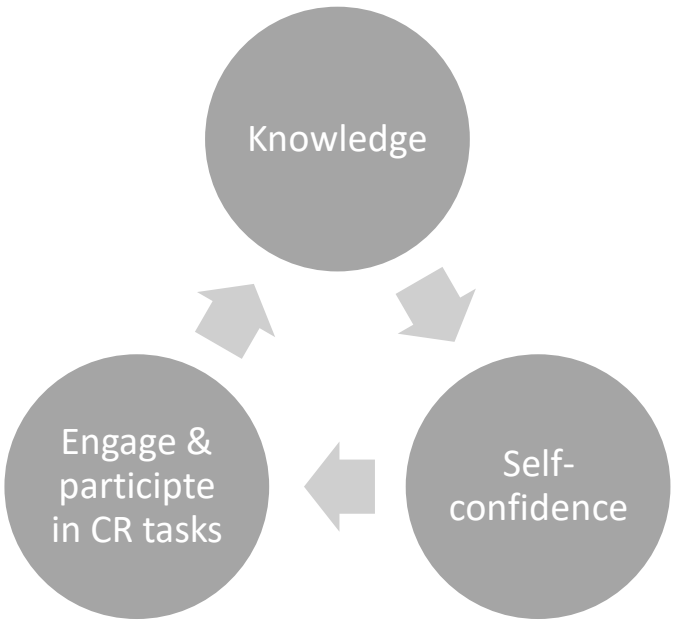

Figure 17: Cycle of knowledge, self-confidence and engagement

Students also noted that you needed knowledge to participate but once you have confidence in your knowledge base, it made it easier to participate. (Student_13_reflection)

Throughout the development of this CMOC the researcher was mindful that knowledge is only deemed adequate or good in relation to the case. If the student already has adequate illness scripts relevant to the case, the student will be able to participate in more elements of CR which enables more learning. This point was highlighted by one of the clinical teacher participants.

> "…you have to be careful of what patients you give to them, so you won't give them the follow up, you won't give them the complex early presentation. The straightforward cases they go, and they feel oh they've contributed, they manage, they knew what the diagnosis was." Teacher_05

To ensure that students have adequate knowledge, teachers ensured that towards the beginning of clinical attachments, students would acquire the basic level of knowledge required to participate.

> "...some didactic teaching around subjects, so Parkinson's and osteoporosis which we know they're going to get in clinics and get clinical exposure to, so it' gives them a point of reference and it gives them something to build on so they're not completely blind into those sorts of environments." Teacher_01

Teachers also suggested that they can assess whether students' knowledge is adequate dependent on the types of questions that they ask, they can infer what they might be thinking about and infer their CR process.

> "So, when the students ask his colleague about oh have you lost any weight, do you have night sweat, have you had any change in your voice, I kind of know what they're thinking about." Teacher_05

> "…you know, this lady comes with a urogynae problem, let's use targeted urogynae questions instead of asking about flights of stairs, cats, etc." Faculty_02

Students understood the importance of having enough working knowledge of a problem to be able to participate in the CR task but that you didn't need to know everything as there would always be something new to identify.

> "…the more you understand about it beforehand, I think a lot of the time the more you can get from it. Because you need the right balance of having some new information so that you learn more stuff from it. But then if you don't even really understand what they're presenting with or what they've got… I don't feel I really got much from any of the patients that came in with musculoskeletal things because I just didn't have enough background knowledge to really use that knowledge and put it into practice." Student_03_interview

From the realist review, knowledge was conceptualised as high or low but from the excerpt above, the idea developed that rather than high knowledge, it was adequate knowledge specific to the clinical case that enabled participation in the CR task.

Participation in CR tasks can also be achieved by observation of others participating in reasoning. There is a notion that observation is not a useful task but what is truly of importance during observation is what is going on inside the student's head at the time of observation. If students are passive and therefore not thinking, this is not useful, but on the other hand, if they are actively listening and cognisant of the potential diagnoses and reasons for the questions being asked, this is more useful to CR development. Observation may be of other students or doctors and through various interventions including real patient interactions or simulated patients. The key context to ensure that observation enables cognitive participation is that the student has adequately high knowledge of the clinical case.

> "…if I'm just observing, I will just try and stand close to the person maybe that's scribing and read what they're writing when they're scribing down what the consultant is doing, or just picking up on any sort of management plans that they're coming to and then in my head to try and think why they're coming to that." Student_04_interview

When students have a good knowledge of the clinical case, they are more likely to follow the reasoning processes of others and be cognitively active leading to participation in the CR task.

> "…if you watch other people take histories, or if you practise taking histories from people for OSCEs, usually friends or people within your group, then you can have a rough idea of their thought process, just from what questions they're asking." Student_05_ interview

Pre-existing knowledge and self-confidence are conceptualised as contexts in this research but building confidence and the consolidation, clarification and refinement of knowledge are theorised to be the mechanism responses in this CMOC. Consolidation, refinement and clarification of knowledge is akin to learning in its most general sense. It is not enough to purely acquire knowledge, one must build on existing knowledge, refine, consolidate and clarify it to develop. Because this is a mechanism it is not amenable to empirical data capture and has been retroductively theorised as being the causation of outcome. Building self-confidence in students' knowledge base is also important to enable future engagement in tasks which require participation in CR tasks.

Refined CMOC: Participation in clinical reasoning tasks; Student adequate clinical domain knowledge.

Students who have an adequate clinical domain knowledge (C) who participate in clinical reasoning tasks (Mresource) can understand (Mresponse) and consolidate, clarify and refine their existing knowledge (Mresponse) in relation to the patient's presenting problem. This builds self-confidence (Mresponse) and overall has a positive impact on the development of clinical reasoning (O).

Student low clinical domain knowledge

If the knowledge of a case is lacking students may only be able to gather information in a haphazard manner and not be able to form appropriate differential diagnoses or problem representation. This prohibits them being able to participate in all elements of the CR process (Daniel M et al., 2019). Early in clinical practice this was expected by faculty:

"…initially they're going to get loads and loads of information; some of it completely irrelevant." Faculty_02

"…student in an early clinical experience with a patient is likely to take a very inductive history where they just gather everything… [an] amorphous blob of information." Faculty_04

Students also confirmed that in the early part of their clinical practice they would gather information in an unstructured fashion from patients without thinking about the reason for doing this.

"I don't think I had any of it in CP1, I think I just regurgitated the same history every time I spoke to a patient and never really narrowed it down." Student_02_focusgroup

"When I was asking in the history asking questions, I think I was so kind of preoccupied with thinking of what questions to ask that I didn't think about the differentials as much." Student_03_interview

"You just got through the motion of asking and not thinking about the answers." Student_01_focusgroup

Sometimes, the students would be so focussed on the questions they needed to ask to gather the information that the detail of the answers would

be lost which would become apparent in the lack of ability to show empathy and in the inability to discern the likely causes for the patient's problem.

> "During OSCE practice last week, a student asked about family history and the patient said 'Oh, my father died last week of a heart attack' and the student said 'ok, that's cool' because that just shows how much they're thinking about, they're not thinking about the answer, they're just so focused on asking the questions in the right order." Student_02_focusgroup

> "I realised that actually, although I might have taken a history and thought the differentials were obvious, I then get to the end and mentor would say like and 'what are the differentials', I would actually struggle. I hadn't realised that I wasn't doing that." Student_01_interview

Some of the student's inability to reason through a patient's problem may stem from lack of instruction that this is the purpose of gathering information from a patient, it may be a lack of knowledge of the clinical problem or the cognitive load of simultaneously gathering information and using this information to reason through potential diagnostic hypotheses is too high for some students.

From the realist review, it was suggested that lack of clinical domain knowledge may account for students not being able to focus on purpose of gathering information from the patient.

> "If a differential doesn't pop into your head, you can't ask about it and then you can't ask the specific questions." Student_03_interview

Some students mentioned certain specialties where their knowledge base was lower which made taking histories more challenging as they didn't know what the potential diagnoses could be which led to feeling of inability to participate in CR tasks. In these cases, the students also noted that once they had learned the basic knowledge required within that clinical domain, they felt more able to participate (Student_07_reflection). Students appreciate that talking to patients and active participation in CR tasks is important but without adequate knowledge, it would feel a waste of time to do this (Student_08_reflection).

Clinical domain knowledge was highlighted by the clinical teachers as being key to whether students would be able to go beyond gathering information, from just rehearsing the steps they knew verses considering the potential differential diagnoses and focusing on these. The lack of clinical domain knowledge was important in both gathering information from the patient as a history of the presenting problem and in performing appropriate clinical examination.

> "They didn't have the background knowledge to match with the steps that they'd been taught, steps and the procedure. So, they couldn't fill in the gaps and come to a diagnosis." Teacher_04

> "Teaching them to do clinical examinations in the first and second years with very little clinical knowledge, they can remember how to do a clinical exam but as soon as you ask them why, they won't know why as they haven't had the clinical experience to know why they're doing it." Teacher_01

The students with lower clinical domain knowledge were more likely to be passive in gathering information and rehearse the steps in CR rather than actively generating the hypothesis and considering differential diagnoses (Daniel M et al., 2019). This is expected in early years' students, but in clinical years knowledge is required to enable students to participate in these activities. Without being able to fully engage in all aspects of the CR process, students have less opportunity to consolidate, refine and clarify their clinical domain knowledge. There may be some educational benefit to developing CR, but it is less than those students with adequate clinical domain knowledge as not all aspects of the CR process are considered.

Refined CMOC: Participation in clinical reasoning tasks; Student low clinical domain knowledge.

Students who have a lower clinical domain knowledge (C) who are exposed to real patient interactions, simulation, and virtual patients (interventions) are more likely to be passive and rehearse the steps in clinical reasoning rather than actively participating in clinical reasoning (Mresource) which reduces consolidation, clarification and refinement of knowledge (Mresponse) and reduced impact on CR development (O).

Student clinical experience and goal orientation.

During the realist review, student clinical domain knowledge, self-confidence and coping strategies were found to be the individual students' contexts affecting educational interventions in developing CR. Researcher experience presupposed that graduate-entry medicine (GEM) students may be

more able to participate in CR tasks than undergraduate students. However, during the interviews some undergraduate students also seemed to be able to participate in CR tasks with ease which led to refinement of theory by considering what it was about students that allowed them to readily engage in CR tasks.

Students who felt that their input would have an impact on the patient, felt involved in the patient's care and understood that there would be a real impact on the patient. For some students, such as Student_01 who had a background as an administrator in a hospital before graduate entry medicine, the appreciation of the importance of their input into the patient's care had a positive impact on their own learning.

> "I felt that I learned a lot and improved a lot in terms of my presenting. Because I was genuinely presenting to professionals who were going to use that information to then see the patient." Student_01_interview

This student also stated that their experience of working in a hospital enabled them to understand the job of a doctor and the sense of responsibility was good for them and they were appreciative of the participation in patient care.

> "It's not about can you do things perfectly to get full marks in your exam, it's about what can you actually do." Student_01_interview

Other students with a background of working in a hospital found that they were more able to learn in the clinical environment as they understood the setting, felt comfortable, and this enabled engagement.

> "Knowing how wards work, how hospitals work, what the ideal of a patient journey might look like. I think knowing what a ward round is and what the aim of a ward round is, I don't remember being told that as a medical student, but I experienced it from a nurse point of view. So, I think especially at the beginning of the clinical phase, people will be like I don't know where to be and I don't know what to do on a ward. And I think it's an environment that I found quite comfortable. So being able to be on a ward and not feel like completely in the way." Student_02_interview

This student was able to speak to patients in a clinical environment with ease which is likely to suggest they had lower extraneous cognitive load.

> Researcher: "Have you found from your experience that you're feeling comfortable or that ward environment makes it easier for you to go and practise those skills?"

> Participant: "Absolutely, I think not being frightened of patients is a real benefit. Because it just means that you don't have to work yourself up for it; you can just go and quite naturally have a conversation, not just with a patient but with their family." Student_02_interview

This student was able to articulate where clinical experience may have come from and suggested that this was beneficial in the introduction of CR teaching in the early stages of their course (GEM student).

> "…many people had worked before or had been around sick people before or had some work experience and lots were HCAs so speaking to patients, it wasn't the first time it had happened." Student_04_focus group

Students with clinical experience were better able to understand the purpose of training to become a doctor and felt more at ease in clinical settings but the same findings were found in some students without clinical experience. Perception of the reason for learning for clinical practice rather than just assessments is called a mastery goal orientation (Chen et al., 2016) and was felt to be importance for engagement in learning.

> Participant: "I do more then I think that is why you do it. It's not because that's for the OSCE. It's not for the OSCE so you learn."
>
> Researcher: "That's really interesting. So, you see that actually it's important you're learning something for clinical practice rather than just for the exam."
>
> Participant: "Yeah definitely." Student_02_interview

Reflections on other students' comments also reiterated the importance of goal orientation to engagement in activities to promote CR development.

> Would prioritise certain things over others, not enough time to do all, would prioritise activities that would promote being a good FY1. Student_14_reflection

> Takes pleasure from CR tasks, has a mastery goal orientation. Realises that some things can be checked on the job, but not everything. More important to get the basics right in the undergraduate experience. Student_10_reflection

For some students, they had connections with people who were already working as doctors which enabled them to understand the importance of being able to do the job of a doctor and encouraged them to engage and learn as a student.

> "When I go on a ward, I've got friends that are foundation or early core trainees, and I just hear their experiences and think I definitely want to be prepared when I get there. So yeah, when I'm on a ward round or something, I just want to make sure that I'm practising it enough that when I got there, I wouldn't miss things." Student_04_interview

In realist research, examining the contexts where the outcomes are different can help illuminate the most important factors affecting outcome. In contrast to the students who demonstrated a mastery goal orientation, this student highlighted that focussing on assessments has made learning harder for her in the longer term, reinforcing that a goal orientation towards mastery has a positive impact on CR development.

> Interested in doing what is required to get through the exams. 'Just need to get through this' but now going into clinical phase, the focus on exams is making it harder for her. Didn't realise what would be required to work as a doctor. Student_09_reflection

Faculty participants also noted that goal orientation was important and that for most students, this is how they would choose to be taught and to learn.

> "…most students this is what they want. When they apply to medical school, they want to see patients. They want to learn in clinical settings." Faculty_04

Whilst some students enter medical school with clinical experience and a mastery goal orientation, some do not and for these students, it is important that their medical school experience prepares them to gain the most out of learning in the clinical environment.

> "I think partly the course structure at Nottingham is to blame for the lack of clinical exposure. And I think that's something that needs to alter before they get into specialties like O&G, paediatrics, especially if they're going to be shortened, to give people those core communication skills and abilities to almost hit the ground running." Faculty_02

The course structure at Nottingham whilst this research was taking place, limited the clinical course to 2 ½ years as students were required to undertake a 6-month BMedSci intercalated research degree as part of their studies. In many medical schools, intercalation to undertake a research degree

is an option but not mandated as it is in Nottingham. Subsequently many teachers and faculty members believe clinical contact is unduly shortened for Nottingham medical students. This does highlight the degree of importance that medical teachers place on clinical contact to develop CR ability. The curriculum needs to be able to prepare students to learn in the clinical environment and later sections will discuss how this might be achieved. Students place emphasis and importance on educational intervention that enables interaction with real patients and understand the benefit of this to develop CR as this is affiliated with doing the job of a doctor reinforcing mastery goal orientation.

> "I think the fact that it was just real patients, and there was lots of extra information that you didn't necessarily need that you wouldn't have got with a patient actor or with something else. And so, it just felt a bit more like you were actually doing what you might end up doing as a job." Student_05_interview

Medical schools often suggest to pre-clinical students that seeing real patients and spending time in the clinical environments is vitally important for CR development but as this student highlights, at the beginning of medical school, this information is lost to students without prior clinical experience.

> Researcher: "The messages that you are getting from the university are saying that it is useful for the long term but actually you can't see that right at the beginning of the process."

> Participant: "Yeah you can't see it. And how could you? Even less so if you're 17 or 18."

Researcher: “But perhaps easier if you’ve already gone through the process or maybe already worked before?”

Participant: “I think so. Especially if you worked in medicine, because I can look at where I was in terms of contributing to patient care.” Student_02_interview

Overall, analysis of the data showed that students with previous experience were not frightened of speaking to patients and were better able to negotiate the clinical environment. These data were theorised to contribute towards the mechanism’s response of lower extraneous cognitive load in the clinical environment when learning. Students also articulated that their previous experience or their mastery goal orientation allowed them to see how their input affected real patients, they understood what it was to be a doctor, or they knew they needed to learn these things now so that they could be better FY1’s. These aspects were theorised to contribute towards a mechanism response of appreciation of the importance of participation in CR tasks. Overall, a mastery goal orientation or previous clinical experience enabled students to engage in activities that enabled participation in CR tasks to develop the CR ability.

Refined CMOC: Participation in clinical reasoning tasks; Student clinical experience and goal orientation.

Students who have previously worked in a clinical environment OR have a mastery goal orientation (C) are more likely to appreciate the importance (Mresponse) of participation in clinical reasoning tasks (Mresource) OR have a reduced extraneous cognitive load in the clinical environment (Mresponse) which leads to greater engagement (Mresponse) in these activities which has a positive effect on CR development (O).

Student low self-confidence, motivation, or knowledge

The realist review demonstrated the importance of clinical domain knowledge and self-confidence to determining effectiveness of CR educational interventions. During empirical data collection, these were key contexts to examine. During the realist review, whilst appreciating that multiple contexts are interdependent, knowledge and self-confidence were treated as mostly independent contexts. During the data collection in the realist evaluation it became clear that clinical domain knowledge and self-confidence were linked and both contexts affected engagement. In the realist review phase of the research resources of simulated environments that promote authentic real-life situations and teaching in the real world were hypothesized to be affected by contexts of student self-confidence, self-efficacy and coping strategies. In this phase of the research, these resources were redefined as participation in CR tasks and the contexts were a starting point to be refined by the realist evaluation.

Faculty and clinical teachers highlighted that knowledge and self-confidence were linked when discussing educational interventions that required a student to interact with a patient or participate in a CR tasks.

> "So, it does depend on not just the knowledge base, but it also depends on how comfortable they feel in an environment for them to be able to talk." Faculty_01

> "…there are some people that if you get them to have a go at prescribing something will freeze up a little bit, because it is, perhaps maths isn't their thing. Perhaps they've tried doing bits in the past and found it really confusing. So, I think some of it is probably as much about confidence as it is about knowledge." Teacher_03

> "Sometimes it's knowledge and some students just absolutely can't remember steps of the examination, or don't understand the pathology. I think a lot of it is their own self-confidence or self-belief in whether they can do it. I think that has a big implication, because there are quite a lot of students that actually are quite able, but really feel like they need the support." Teacher_04

> "They are good, they know their stuff, but they just don't want to be in the spotlight." Teacher_05

Both teachers and students appreciated that confidence is something that takes time to develop but it comes with practice and experience.

> “It took me a while to just get confident at, I used to have to build up the courage to go and chat with patients, I used to be really scared and that did come naturally but it did take a lot of time to build.” Student_02_ focusgroup

> “I think young doctors, medical students, are reluctant and nervous when they talk to patients. And I’m sure I was when I was younger. But only by doing things will you become better.” Faculty_02

Some of the development of self-confidence comes with acquisition and development of knowledge. The more knowledge a student acquires the more confident they feel in the clinical setting, which enables further engagement and knowledge acquisition. Researcher reflection on data provided by these students demonstrated again how knowledge, confidence and engagement are connected.

> Don’t feel confidence going into the clinical environment without having the knowledge. Student_12_reflection

> Might have low motivation to participate as lacking knowledge and therefore confidence. Didn’t understand topics well, so onwards, can take history as doesn’t understand relevance of symptoms and treatments. Might prevent participation, didn’t go into the ward as often as she could have. Student_12_reflection

> Whether or not she would therefore spend more time on the wards would depend on her knowledge and how confident she felt with her knowledge of the clinical problems. Student_15_reflection

A similar effect on engagement was described as affected by student motivation. Some students noted that motivation fluctuates, and this may be impacted by external factors such an interest in the medical specialty or other external factors such as tiredness or hunger (Maslow's (1943) hierarchy of needs).

> "95% of the time, it's going to be watching and asking questions and if you're not necessarily interested or you're feeling a bit unmotivated that day, it would be so easy to just sit quietly." Student_04_interview

Motivation to participate is also linked to self-perception of knowledge and self-confidence.

> Might have low motivation to participate as lacking knowledge and therefore confidence. Student_12_reflection

Teachers spoke of the challenges associated with students who appear to lack motivation.

> "The one who sits there, the student who sits there in the corner going 'I bloody hate this, I don't want to be here', it's hard to motivate enthusiasm to push that student". Faculty_02

Motivation is a complex psychological driver of behaviour but there are many theories of motivation (Cook and Artino, 2016). In this research, goal

orientation theory was used as the main motivational theory in students behaviour and desire to engage and learn in the clinical environment, although the points raised here also pertain to self-determination theory (SDT) since drivers of behaviour can also link to intrinsic motivation and interest (Cook and Artino, 2016). When students have a mastery goal orientation (see previous section), students readily engage in activities that are perceived to help them develop as doctors but when students have a performance goal orientation this may limit engagement in certain activities.

> Students driven by assessments or performance goal orientation – assessments might not encourage students to be on wards or be inquisitive. Can pass exams by reading book or doing past questions, recognising key features in the way the questions are written. Student_07_reflection

> Exam wants a lot of detailed knowledge but in reality, can you remember to order the correct blood tests. Disparity between expectation of the job and the exam. Doesn't encourage gaining lots of experience which is important for CR development. Assessments encourages a performance goal orientation rather than mastery orientation; the clinical environment doesn't favour this. Student_08_reflection

From the realist review results, fear and stress of anxiety were hypothesized to be mechanism responses in students with low self-confidence or self-efficacy when exposed to real-life situations or real patients. These emotional mechanisms were noted by some participants:

"So, lots of them just have this performance anxiety of 'I can't do it.'" Teacher_01

Fearful of wasting time – feels very time pressured, talking to a patient when you have low knowledge feels like wasted time. Fear of failing. Student_08_reflection

Overall, these emotional responses affected engagement in educational activities that enable participation in CR tasks. Engagement in activities is a cognitive response of the students and determined in this case by their pre-existing knowledge, self-confidence, or motivation.

As previously stated, Figure 17 shows the connection between knowledge, self-confidence, and engagement in participation in CR tasks. Indeed, what is perceived by educators as low knowledge may in fact be lacking self-confidence and vice versa. Some students may also lack motivation generally or other external factors impact their motivation to participate at certain times. All these contexts affect attendance and engagement with tasks that enable participation in CR.

Refined CMOC: Participation in clinical reasoning tasks; Student low self-confidence, motivation, or knowledge.

When students lack self-confidence OR motivation OR knowledge in the clinical environment (C) this leads to decreased attendance and engagement (Mresponse) with participation in CR tasks (Mresource) which reduces opportunities for CR development (O).

Student perception of assessment practices

Having sufficient knowledge to be able to participate in CR educational activities is important but throughout the data gathering in the realist evaluation, participants highlighted misalignment of learning in the workplace and assessments.

> Across all faculty interviews, they want the students to question and learn from the job or learn for understanding but students often actually learning for the exam and the examination processes don't align with teachers views of learning for the job, students may be more compelled to want to learn for the exam. Researcher_reflection

This was noted as being partly the curriculum at Nottingham having knowledge-based outcomes and long lists of intended learning outcomes.

> "There's a knowledge-based economy within the curriculum. And actually, that's inhibitory in terms of encouraging students to see the core things as transferrable from one clinical context to the next. They're focused on the knowledge-based outcomes of the course rather than the integration of everything and around being able to approach any patient." Faculty_04

But there was a drive for this to change and during the research period a curriculum update was underway where one of aims was to encourage students into the workplace.

> "We need to push them into the workplace and then, and not see the workplace as a tick box exercise." Faculty_04

Most students appreciated that they needed to experience real patients and the real workplace to develop their CR skills.

> "I think by the time they [other students] get to their clinical years, [they] realise the answer isn't in the book." Student_05_interview

However, this was not the case for all students including this student who failed one of their clinical examinations who perceived that factual knowledge would be required to pass the exam.

> 2 goals; exam and do what university need AND what do I need to know as an FY1 and is practically useful – not perceived as the same thing. Exam wants a lot of detailed knowledge but in reality, can you remember to order the correct blood tests. Disparity between expectation of the job and the exam. Doesn't encourage gaining lots of experience which is important for CR development. Student_08_reflection

This same student perceived that because the university and the medical course requires students to pass assessments to progress this led to a subliminal message that you just need to get through the exam which discourages engagement in clinical experiences that would develop CR but is not perceived to aid them pass the assessments. (Student_08_reflection)

Clinical teachers also noted that the assessment practices and the students' perceptions of them also discouraged attendance, engagement, and participation in CR activities.

> "I think some it comes from the messaging from the school itself, I think medical schools, not just here but all medical schools, signpost the student towards 'you need to get through this exam' and they provide a very long list of learning objectives which might potentially be assessed, then naturally they're going to go 'well I need to get this done as that might come up in my exam and the shortest route to getting there is if I spend time in the library and in the books and not necessarily on the wards and the problem with that is, is that it neglects or discourages students from going 'well actually, I could get an awful lot out of this if I go to the wards and it discourages students from necessarily spending their time in clinical and real world experiences." Teacher_01

This same participant noted that there is a cross over between the student's goal orientation and perception of what is required by the assessments. If students are very tied to their learning objectives, they sometimes will not buy into activities that enable participation in CR and they cannot see why these activities might be useful for them in the future as doctors. (Teacher_01_reflection)

> "There is a significant proportion who are so driven by assessment that it's quite hard for them, quite hard to see the bigger picture." Teacher_01_interview

Some students felt that the clinical settings were too unpredictable and uncertain to be useful for undergraduate learning which is relevant for their assessments.

> Difference between uncertain, ambiguous environment of medicine and how undergraduate medical education is taught and assessed. So, undergraduate medical studies, exams are the most important and then learn CR properly in PG training. Student_10_reflection

Assessments are known to drive learning and when assessments are not aligned with experiences offered to students, this may discourage students away from the workplace. Despite this, teachers consistently remind students that practical experience is necessary and important and infer that students who heed this advice or ensure they have real world practical experience will be better in the longer term.

> "You can tell the students who have got real world experience, you can tell the ones who have spent time on the wards and what they say is based around people, based on cases and experiences rather than based around text book and text book knowledge and we'll all say it and we'll say it a million times again, get to the wards and practice on patients and there will be a portion of them who will do that but around exams time there will be a proportion of them who just want to hit the books and 'this is what I need to get done and the quickest way of me getting there." Teacher_01

Other participants noted that spending time in the clinical environment would be determined by the imminence of their assessments, suggesting at these times, factual knowledge acquisition and non-clinical or non-workplace learning would be preferred.

> Students driven by assessment, if you tell them it's not helpful for an exam when exams are coming up, they won't be as interested, no matter how much they like this teaching. To get the student motivated in teaching, it must be relevant to the exams when the exam is looming. Teacher_02_reflection

> Students would vary their priority to where to spend their time at certain times of the year. For example, nearer the exams they wouldn't spend so much time in the clinical environment – many preferring the library etc. nearer to the exam – people's attitudes changes, feel they need to learn for the exam etc. attention is then shifted in the months before the exam. In the middle of the year – enjoy the placements more as less added pressure so feel better able to take time and see extra things. Student_14_reflection

> Can see why people avoid clinical attachment prior to the exam, written exam could learn from a textbook but not the OSCE. Feels easier to go to the library but harder to practice on the wards for the OSCE. Student_13_reflection

In the focus group, when asked about whether students would often spend time in the clinical environment, they responded thus:

"I think at this time of the year when exams aren't very close, I would think, if it makes me a better doctor then it's all very good but I suspect a few months down the line when exams are looming then I would think that's not going to help me pass the exam, and it's not going to help me learn all the textbook objectives we need to know, I would prioritise things that I think would help me pass the exam which is sad but maybe the way it is." Student_focusgroup

Overall, students' perceptions of the assessment practices which are closely linked to their goal orientation and the imminence of the educational intervention to the assessment were key in determining engagement and subsequently their opportunities for participation in CR tasks in the clinical environment.

Refined CMOC: Participation in clinical reasoning tasks; Student perception of assessment practices.

If students perceive assessment practices at their university are based on factual recall of knowledge or without many opportunities for application of knowledge (C), OR their examinations are imminent (C), they are less engaged in the clinical environment (Mresponse) which reduces the opportunities to participate in CR tasks (Mresource) and reducing opportunity to develop CR (O).).

Teacher motivation, actual or perceived time to teach and physical space.

As previously noted, the lead researcher was a clinical educator and doctor, which enabled insight into the realities of educating students in the clinical setting. Although deemed as very important, it was postulated that several challenges would arise that would prevent opportunities for students to participate in CR tasks in the clinical setting. This was viewed by students and teachers as a very valuable educational experience.

> "Some of the outpatient clinics I've been to have been amazing, and I find taking history is very useful. And then especially you can then talk about that history with the doctor, and then either they discuss it quickly with them and then they ask more questions when they see the patient". Student_05_interview

Physical space such as available consulting rooms to enable students to speak to real patients in clinic settings or the numbers of students required to be on a ward were highlighted as being a problem.

> "I am still amazed that students come away from clinics being told that they can't sit in with patients, they can't sit in with consultants, they can't have a room. You know, I think the discussions that we had at our last meeting about infrastructure, that there isn't a room for people to take history is just shocking". Faculty_02

> "I think it's some of the current climate of the NHS. It's just, it's hard to take a group of eight students and allow them to be immersed in a ward

round…the feasibility of all students being out on the wards is just, it's not going to happen, there's too many of them". Teacher_07

Whilst physical space was mentioned, time was a bigger factor for many participants.

"It is time pressure. If you're having 15 patients in the clinic, you may, you would not have time to explain, not everything, but not every important thing". Teacher_05

"I think clinicians' time, if you do have a student with you, it does slow you up, you do go slower. If you're going to spend the time articulating what you've just done or asking them questions, it takes a little bit longer, and I think the time pressures of your clinical workload is a barrier. So that's one of the reservations in the emergency department." Teacher_04

"If you get a consultant to stop after every patient, you can imagine that clinic will last all day. So, I think that is a barrier, and I think that's why they end up just standing watching in the end because the consultants almost got no choice but to just rattle through and hope that they pick something up by watching." Teacher_04

"It's usually running quite [late], you know, you've got 15 patients in a clinic. Even though we manage to try and reduce the clinics, the time is limited. Patients may not want to spend an extra 20 minutes talking to the student. Most patients are OK, but you've got to find another room, for example, to sit them down and take that history. They enjoy it. They

love it when they can get the opportunity, but it might be limited. Not all of them would get it." Faculty_01

This participant noted that a lack of time led to students feeling aware of the pressure on the doctors which discouraged them from asking questions to aid their own understanding as well as not being able to participate:

Researcher: "And time is a big factor, isn't it?"

Participant: "A massive, massive factor, yeah. A busy ward round, sometimes it's not, you just have to watch; you can't really ask as many questions because time's such a, they seem really stressed and you don't want to interrupt their train of thought and things." Student_04_interview

Some participants noted that extra time was required in order that adequate and effective teaching was possible:

"In my general practice I have 15-minute appointment times so I kind of allow time for…I find that more satisfactory from my own practice point of view, but it's certainly much better when you've got a student in with you. Because it means that instead of me seeing the patient and the student watching or the student seeing the patient and me watching that quite often there's an element of time for collaboration that we're seeing the patient together." Faculty_04

Time was noted to be a challenge but some teachers recognised that teaching was mandated and therefore despite the clinics being busy, it should be accepted that teaching should still be undertaken and therefore a lack of time could be perceived rather than actual lack of time.

> "Every student should, if they're going into a clinic should be able to go off with a patient, take a history and present that patient. In a busy clinic that may only be two or three patients. But if they're not doing it the system is failing. And I'm gobsmacked that we haven't got the infrastructure. I run a busy gynae clinic. If my students come, they will be sent off and see five patients. See all the new patients, go, and take a history, come, and present them. If we overrun a bit, we overrun a bit." Faculty_02

This highlighted that teachers' also need to be motivated to teach in clinical settings when time and resources are limited.

> "There are challenges with capacity, infrastructure, clinical clinicians' time to teach, but ultimately if you put a student and an enthusiastic clinician and a patient in a room and it will be a positive experience for the student, and they will benefit from it". Faculty_04

> "If the doctor that you're in the clinic with isn't particularly bothered about you doing it. So, they're not going to find space for you". Student_05_interview

> "The person has to be happy to teach". Faculty_02

"Some of the clinics have been really good in terms of they'll let you go to talk to the patient first and then you feedback, and they'll ask you what do you think we should do next. But again, that's really dependent on the consultant you're going to get as to whether they've got the time." Student_04

"So, he kind of built his clinic when there is a patient that actually a student's for the benefit of the clinic, rather than slowing the clinic, which is quite a clever approach to develop. So, the student [would] go and take the history, listen to all relevant detail from the mum, and then come and compact the story to the consultant in let's say two or three lines. So, the consultant has an idea about what's going on. And then when the patient comes, when he asks only the targeted question and examine them, it will be a shorter consultation, because there is already some work has been done. And then it's learning for the students and time effectiveness for the consultant." Teacher_05

Participants offered suggestions to ensure that teaching CR was effective despite the practicalities of lack of time and space.

"…the feasibility of all students being out on the wards is just, it's not going to happen, there's too many of them. But how do we work round that to help students to pull together all these different things, which seem a bit disjointed? They've got some really good bits of teaching from lots of different things, but the only way it can all come together is out there, or in really good simulation." Teacher_07

Students stated that they often felt teaching in the clinical settings was ineffective which made some students resent attending clinical placements as they did not feel it was useful. Lack of attendance will mean lost opportunities to participate in CR tasks. This student felt that the reasoning for this was related to time, space, resources and lack of teacher motivation:

> Time and place and resources might stop students getting experience – felt like a piece of furniture. Then feels like would be more effective to learn from a book rather than just sitting there. Not always possible to be taught in NHS setting. Don't always feel consultants motivated to teach. Student_11_reflection

Overall, participants noted various co-dependant contexts within the wider educational setting combined with educator motivation to teach which contributed to students being enabled to participate in CR tasks.

Refined CMOC: Participation in clinical reasoning tasks; Teacher motivation, actual or perceived time to teach and physical space.

Actual and perceived time to teach, physical space and teacher motivation (Contexts) are all required to allow and enable participation in CR tasks (Mresource) which, through consolidation and refinement of knowledge (Mresponse), develops CR ability (O).

Student self-confidence, teacher confidence and student-teacher relationship.

From the realist review, self-confidence and coping strategies were key contexts in determining engagement in educational activities to develop CR but mainly focussed on these contexts effect on students' emotional responses to either real-life or simulated teaching settings. In this phase of research, the data gathered included the effect on any educational intervention, but this section specifically focusses on the effect on participation in CR tasks.

Students in the research noted that their self-confidence was an important factor in enabling participation in CR tasks.

> "…it's very much those that are the loudest that probably get those experiences more. So, I definitely think self-confidence helps." Student_04_interview

> High self-confidence – willing to go forward into the experience, happy to accept feedback and what he should improve on. Confidence increases opportunity to practice. Student_06_reflection

Self-confidence to participate was also determined, as previously noted, by a student's perceived knowledge within a clinical domain.

> Knowledge – need knowledge to practice, if you have confidence in your knowledge base, makes it easier to participate. Student_13_reflection

Students need to have an appropriate level of self-confidence relative to their ability and knowledge. Some teachers noted that having good self-confidence levels that did not match ability could lead to harmful.

> "…a fairly normal almost compensation for feeling a little bit anxious, a little bit uncomfortable. So, 'I don't want to not be able to do it, and I don't want to look hesitant or not very confident, so I'm going to almost over-compensate', and you just hammer straight in quickly and probably not very accurately." Teacher_04

Teachers were aware that students' perceptions of their ability within a clinical domain would affect their self-confidence and subsequently their engagement with the clinical environment, in this case outside of scheduled teaching time.

> "So, it makes them go oh I think I've grasped this, I think I can go back in my own time." Teacher_02

There may not be continuous teaching staff presence in the clinical areas during students' rotational clinical placements and so to make the most of every opportunity, students need to feel able to attend and engage with patients on their own. Building self-confidence in their ability and in the clinical environment makes these settings more accessible to them which again increases engagement in clinical environments and participation CR tasks.

Clinical teachers also can enable engagement in CR tasks when students have lower self-confidence. Over time, the engagement and subsequent increase in knowledge will have a positive impact on most students' self-

confidence. For teachers to enable and encourage students to participate, teachers need to trust the students. Rotational clinical placements without continuity in teacher-student relationships that mean that trust in students' knowledge and ability is not developed which has a negative impact on the student's ability to participate in CR tasks.

> "Every time [the students] start somewhere new, [the teachers] don't trust what anybody else has taught [them]. Or 'we don't believe that you've learnt anything'. And that's a very negative message to students. So, the hub structure will hopefully enable there to be greater confidence that students have transferrable learning and that we will be able to build that up over time." Faculty_04

Trust in students is important for allowing them to participate in CR tasks, it was vital to consider the factors that enabled trust to develop between teachers and students. It was recognised that different clinical teachers have different ways of approaching teaching.

> "So, you can't standardise how you deliver teaching in those settings. Very mixed, some [teachers] are very much, you know, 'you are here a member of the team, start seeing patients', in a supportive way. Others are, 'you can sit in with me' and you know. I use the analogy, it's a bit like surgeons who when you're a trainee some consultants will let you do lots of hands-on. Others are very risk averse and want to make sure you can talk through everything fully." Faculty_05

> "Some clinicians will go over it again anyway because they don't trust anybody. That's the way they are. And some are very laid back and will

trust anything anybody says. But most people are in the middle somewhere." Faculty_04

When teachers had high confidence in their clinical and teaching practice, student participation was seen as important and encouraged in clinical placements.

"I don't often give them a choice. I try to say you know what, if I gave you a choice whether you'd want to start seeing patients on the second day of your attachment some of you would say no. So, I said we're going to ease you in gently. You can stop whenever you want, but there's no substitute for starting to see patients…there is no substitute for the hands-on and rolling your sleeves up and being part of a team. And I mean I think that's the thing we need to encourage." Faculty_05

"I see medical teaching that you have to be doing it and if it's an apprenticeship, so the more you see the more you do hopefully the better you will become." Faculty_02

Some trust may develop from the relationship between the student and teacher which enables the teacher to have confidence in the student's ability:

"…once a student has sat in with me and seen me take a history and how I interact with patients I will send them away and say go and take a history. Then come back, present that patient. Initially I tend to get the students to come back, present to me with [the patient] out of the room and then bring the patient in, so they don't feel hopefully too intimidated and feel comfortable about presenting." Faculty_02

> "I wouldn't have thought that I'd have the confidence to be seeing patients on my own without the GP interfering - obviously most of the time she did see the patient, but there was a few times where she was like no you go back, tell them that's the plan, send them away, it was actually really rewarding because I felt more independent in medicine practice than I'd ever done before." Student_03_interview

The importance of continuity in development of the student teacher relationship to enable building of trust was highlighted by one participant who also noted that the current educational system doesn't always enable this due to limited continuous exposure to the same student.

> "In the fourth week of a GP attachment, would that clinician, do they trust most of the history and examination of that student and most of the decision making because what they've seen, they believe, and the student has performed sufficiently, and the student has done enough to demonstrate to them what they can do. Because at the moment, students aren't able, aren't given the opportunity to demonstrate to working clinicians exactly what they can do because their exposure is so tight." Faculty_04

Overall, the students' self-confidence in their own ability, the teachers' self-confidence or a developed relationship between the student and teacher enables the mechanisms of trust and engagement in the CR task.

Refined CMOC: Participation in clinical reasoning tasks; Student self-confidence, teacher confidence and student-teacher relationship

Students who have appropriate and adequately high self-confidence (C) OR who are trusted (Mresponse) by a confident teacher (C) OR through development of a student-teacher relationship (C), can engage (Mresponse) and participate in clinical reasoning tasks (Mresource) which has a positive impact on CR development (O).

Learning from mistakes

Mistakes and errors in learning are inevitable but whether this is seen as a learning opportunity which aids the development of CR, or an event best avoided depends on various contexts. Mistakes can occur during any educational intervention and some educational interventions may be designed such that mistakes are encouraged or forced to occur for the benefit of learning. Simulated teaching environments provide a safe learning space to make mistakes without the concern of detrimental impact on patient care. In undergraduate education, students are very rarely making diagnostic and treatment decisions about patients that are not checked by qualified medical practitioners before reaching the patient. This means, any mistake made by a student is very unlikely to affect patient care and therefore educational objectives should be at the forefront of any interaction a student has with a real patient. Whether this is the case depends on various contexts and factors that will be discussed in this section. In this phase of the research, contexts of student self-confidence and coping strategies were sought to be refined and additional contexts affecting development of CR were exposed during data analysis.

Student low self-confidence and perception of unacceptability of making mistakes

From the realist review, making and learning from mistakes was found to be impacted primarily by student self-confidence and self-efficacy beliefs as well as positive and negative coping strategies. When students had adequate self-confidence and self-efficacy beliefs or positive coping strategies, they developed new understanding and felt safe to make mistakes when this

learning opportunity presented itself. This idea was presented to participants to confirm, refute or refine the programme theory.

Clinical teachers and faculty participants noted that, for many students, making mistakes in any educational activity was challenging. These clinical teachers highlighted that the idea of making mistakes is socially unacceptable.

> “I think you're right that they are scared to make mistakes. And I think it's been distilled into them for a long, long time. I think from the media and the rest of it, it does impact on how they may seem to come across and what others may think of them.” Faculty_01

> “…they put high pressure on themselves that they need to get everything right.” Teacher_07

> Medical students not used to making mistakes, hard for students to accept when they’re told they’re wrong. Student_07_reflection

Clinical teacher participants noted that not wanting to appear unknowing in front of student peers and teachers contributed to not wanting to make mistakes which may impact engagement in educational activities.

> “I think for some students, they don’t necessarily want to appear to have failed or struggled in front of their colleagues as much as anything else. So, I think there is certainly an element of peer pressure, whether it’s actual or perceived.” Teacher_03

"…doesn't want to be seen to be doing it wrong with their peers." Teacher_04

Doesn't have confidence in her ability and knowledge and concerned about appearance in front of peers. Fear of being wrong might prevent her engaging in the activity on occasions. In mock OSCES, being with peer – pressure of making mistakes in front of someone else. Student_08_ reflection

Worried in front of peers and teachers of making a mistake. Student_11_reflection

Participants also noted the significant impact of student self-confidence on mistakes and learning from them.

"…the hesitant student that lacks confidence, doesn't want to do it wrong, or doesn't want to be seen." Teacher_04

"It's more your personality rather than how the educator has taught the session. (SF02 agrees) I think for you [SF02], you're quite self-critical (SF02 agrees)." Student_01_focusgroup

Self-confidence is a factor, might not want to put themselves forward for fear of being wrong. Those who are more willing to make suggestions and be wrong, get a better experience because they're

> happier to interact. Sometimes know that people know the answer but won't expose themselves. Student_07_reflection

> Peers are extremely unconfident and scared in these environments, so scary to talk to patients and touch them, but of course it is something you get used to. Student_10_reflection

Student_01 in the focus group highlighted that the personality of the student rather than the way the educator had run the session was more important for engagement in the educational activity. This was corroborated by this clinical teacher.

> Researcher: "But generally you've found that there are some students that are kind of they don't want to be wrong in front of their peers particularly, and they want to get it right first time."

> Participant: "Yeah, and the thing I can only give you so much in terms of the time I have with them, so I try to do all these sorts of things to break down barriers in terms of make as many mistakes as you want. But sometimes it doesn't work, and I just have to accept that I can't really do anything about it." Teacher_02

The idea that knowledge, self-confidence and engagement in CR tasks was previously noted (see Figure 17). With respect to low self-confidence, this clinical teacher noted that not feeling confident and not wanting to make a mistake prevented student engagement in the task.

> "[The student said] 'I don't feel confident about prescribing, I don't want to prescribe something that will harm my patient', but that was only a teaching session, so she just sat there." Teacher_06

Some students confirmed that they felt making mistakes was unacceptable which illuminated some of the potential mechanism responses for why students may not engage in tasks where they fear making a mistake.

> Lacking knowledge prevented participation as she felt shameful if she couldn't answer questions. Student_12_reflection

> Feels embarrassed, perceived people laughing at her, shame at not knowing enough. Understands making mistakes important, but still feels embarrassed of making a mistake. Student_09_reflection

Clinical teachers also suggested potential mechanism responses relevant to this programme theory.

> "I guess maybe a fear of really not knowing and feeling a bit stupid within the scenario." Teacher_07

> "I think you're right that they are scared to make mistakes." Faculty_01_interview

> "…saying something incorrectly, it can be life or death to them." Teacher_02

To develop CR, it is not just making the mistake but learning from it which is important. In the case of students with low self-confidence or perception that making mistakes is unacceptable, there is no opportunity to learn from the mistakes as these contexts prevent engagement in the CR tasks. From the data, this was inferred to be due to fear, shame or embarrassment of making a mistake.

Refined CMOC: Learning from mistakes; Student low self-confidence or perception of unacceptability of making mistakes

When students who have low self-confidence or those who perceive that making mistakes are unacceptable (C) participate in various educational activities and make mistakes or perceive making a mistake is likely (Mresource), they feel fear, shame or embarrassment (Mresponse) which reduces further and future engagement (Mresponse) and reduces opportunities to develop CR (O).

Student appropriate or adequately high self-confidence

This context offers the alternative perspective on confidence and again was initially developed from the realist review, with students having appropriate self-confidence, self-efficacy and positive coping strategies which enabled them to feel safe to make mistakes and develop understanding through this learning process.

Despite self-confidence being a personality trait, it is not thought to be a static trait in this research. It is dependent on clinical domain knowledge, both actual and perceived by the student, and is a trait that can be developed over time as these participants note.

> "I can deal with a grilling, and I do know I learn better from it, I don't mind it now, but in CP1, I was all new to it, it was too much but you do need to learn to adapt to it and learn from it and not think 'this is me being useless'." Student_02_focusgroup

> "So, I think they just get better from practicing and making mistakes. They've built up their confidence." Teacher_06

> High self-confidence – willing to go forward into the experience, happy to accept feedback and what he should improve on. Confidence increases with opportunity to practice. Student_06_reflection

Some students appreciate the importance of making mistakes in the safe educational environment and have the confidence to continue even when the situation is challenging, they don't know the answer, or they have made a mistake as highlighted by this faculty member's recollection of a student deemed to have appropriately high confidence.

> "…that student I remember so well, and I could see she was completely mortified the minute [she made a mistake] and she didn't want time out… And she goes, let me see, because if I do this in real life, so she set herself a challenge then to say I've dug myself a hole, how do I get out

of this hole because in real life I'm not going to have the time out option." Faculty_05

Students who have appropriately high self-confidence can appreciate the value of making mistakes to learning and are able to reflect constructively on the error as mentioned by these student participants while describing an educational activity of a case discussion.

"So, I would present [the clinical case] to the group in the case discussion and someone would ask 'have they got this symptom?' and I wouldn't be sure or I wouldn't know when it started and it makes you realise the rest of the group are asking because it's relevant and if you have you say 'I don't actually know that' then it's a bit embarrassing. But it also makes you explore the case in a lot more detail." Student_03_focusgroup

Students themselves recognised the importance of their own confidence when approaching educational activities where there is the potential for a mistake, or a mistake was made.

Participant "[Making mistakes] really helped just to get the things that are really essential but easily forgotten into my muscle memory, so every time a patient came with infection, I always make sure get stuff like that or SATS for breathing things."

Researcher: "Do you think it has anything to do with your self-confidence that, you know, you're OK with making those mistakes?"

> Participant: “Yeah, I think so. It does take self-confidence to not beat yourself up too much.” Student_03_interview

Student participants highlighted that some students would be more willing and confident to put themselves forward into educational activities than others. The suggestion here that the teaching situation was relaxed and there were no stupid questions illuminated the importance of the teaching environment and clinical teachers but given that this student participant noted the same few students would volunteer for these additional teaching sessions highlighted something more about the students themselves. This was theorised to be their confidence in the clinical environment and willingness to make mistakes for the benefit of their learning.

> “I was with three other GEM’s, and we would often be in the bedside teaching, for example, together as a four and maybe a couple of undergrads that would sign up to it. And it definitely was a much more relaxed environment because everybody wanted to learn and so there were no stupid questions.” Student_04_interview

Student_04 also highlights that not being fearful of making mistakes increases engagement in various educational tasks which is known to increase knowledge and confidence further, both aiding CR development. This was also highlighted by reflection on another student’s comments.

> Those who are more willing to make suggestions and be wrong, get a better experience because they’re happier to interact. Student_07_reflection

Confidence has been described as appropriate or adequately high, as high confidence without the clinical knowledge or competence can be dangerous for patient safety and result in overcompensation for lack of skills.

> "I think is that over-compensation, so they're going really boldly, too boldly, a little bit too harshly rather than being sensitive to the situation. Because you want to show that you're assertive and you're able and confident." Teacher_04

Overall, self-confidence is a key context in enabling students to learn from the mistakes they make through appreciating their educational value, they can reflect constructively on errors, and they are more likely to engage in educational activities where mistakes may be made without fear or embarrassment. Both learning from mistakes and engagement in various educational interventions aid development of CR.

Refined CMOC: Learning from mistakes; Student appropriate or adequately high self-confidence

When students have appropriate or adequately high self-confidence (C) and make mistakes, they learn from them (Mresource) as they appreciate the value in making mistakes (Mresponse) and they can reflect on errors constructively (Mresponse) and will increase engagement (Mresponse) in CR tasks where mistakes are possible (Mresource), which aids learning and development of CR (O).

Teacher motivation and student-teacher relationship

Although not highlighted as a key context in the realist review, teacher motivation and rapport with students emerged through data collection in the realist evaluation as being important to facilitation of learning from mistakes and the development of this CMOC will be described further here.

For some faculty members who also had roles as clinical teachers, learning from mistakes was seen as important for learning through the mechanism of perceived psychological safety.

> "If they have a safe environment, they are less afraid of making mistakes. And I normally tell them no question is a silly question. You make all the mistakes now, in the two weeks you are with me make all the mistakes, OK, because that's the only time that somebody is going to be there to correct you." Faculty_01

> "…what we're trying to do in these are to say you're in a very safe environment." Faculty_05

Not only do the above excerpts illuminate the importance of psychological safety but teachers specifically highlighting a safe environment to make mistakes demonstrated acceptance and therefore normalisation of mistakes in learning.

> "I will literally tell them if you get that answer right, so what? If you get that answer wrong, so what?" Teacher_02

"We will tend to start off most sessions with essentially suggesting that it is a safe environment in which to make mistakes." Teacher_03

"…you're not meant to be able to do it, otherwise there'd be no point. It doesn't matter if it goes wrong." Teacher_04

"I think they have quite high, they put high pressure on themselves that they need to get everything right. But that isn't realistic, and it isn't how we develop as clinicians." Teacher_07

Normalisation of making mistakes was further illuminated by teachers highlighting their own mistakes.

"I actually share my own mistakes with them and tell them all the things that have gone wrong during my training or during my experience. Just again to make them feel at ease that we're all human and it can happen. And the idea is to share and actually learn from it." Faculty_01

"…when I teach them, they're like 'oh wow you know all this kind of stuff'. You don't know how many mistakes I made to get like and it's good because I made these mistakes, that's why I've become less wrong than I was before." Teacher_02

Furthermore, clinical teachers noted that in medicine, knowing everything is unrealistic, not only do mistakes enable learning but also should

be encouraged to ensure doctors practice with humility and are not afraid to ask for help.

> "…you can't know everything and there are times when you can't remember something, and it's important to know that it's OK to ask someone else, and ask someone else for help or resources, so I do encourage that." Teacher_04

All clinical teachers and faculty participants in the research were motivated and interested in teaching as implied by their educational roles. This factor was seen as key contexts for clinical teachers to facilitate learning through making mistakes through the mechanisms highlighted previously. Student participants confirmed that these contexts were key in the development of this CMOC.

> Some consultants, friendly, engaged, and motivated to teach, really good, would be happy to teach and show different ways of doing things even if you made a mistake. Didn't just make the student feel wrong, just there's different ways of doing things. Student_11_reflection

Some students highlighted that even though their self-confidence to make a mistake was lacking, this could be offset by a teacher who put them at ease. This highlights again the mechanism of engagement:

> Worried in front of peers and teachers of making a mistake, feeling like she shouldn't be there. Wouldn't put herself forward in these situations, more likely if in a peer group of people, she is likely to see

> regularly. Teachers able to make her feel at ease and more likely to engage. Student_11_reflection

Several students noted that they would be able to accept their mistakes and learn from them when the teacher was relaxed and put them at ease.

> Teacher being relaxed and friendly helps, more personable, more conversational, stating not to worry about making a mistake. Student_09_reflection

> Ok to make mistakes or not be sure, as just a learning environment because that's what it is there for. Teachers (CTF's) told students to be relaxed and ok to make mistakes. Student_10_reflection

If a teacher who was perceived as strict or not supportive the student would avoid participation for fear of making a mistake again highlighting the mechanism of non-engagement in the task where a mistake might be made.

> Supportive teacher who allows mistakes, safe environment helpful. If something silly said it seemed fine. If consultant gave a sense of fear of not wanting to make mistake, or if perception of teacher being strict – wouldn't participate. Student_12_reflection

Being able to put a student at ease and allowing them to feel comfortable was theorised to be a teacher being able to build a rapport with student. This was therefore also important context to enabling engagement and learning from mistakes:

"…you have to build a rapport because for the student to be able to comfortably say what's in their head." Teacher_05

If teachers are open and informal, encourage mistakes. Student_14_reflection

Overall, teachers needed to be motivated and able to develop a student-teacher relationship or rapport to make them feel safe, at ease and accepting of their mistakes during learning. When these contexts were present, students were more likely to engage in learning tasks where a mistake might be made, even if their self-confidence was lacking.

Refined CMOC: Learning from mistakes; Teacher motivation and student-teacher relationship

When teachers are motivated (C) and have built a student-teacher relationship or rapport (C), they ensure students are provided with an environment to learn from mistakes (Mresource) which promotes psychological safety, acceptance, and normalisation of making mistakes in learning (Mresponse). This allows students to accept their mistakes (Mresponse), feel at ease (Mresponse) and increases engagement (Mresponse) which all promote development of CR (O).

Student clinical experience or growth mindset

The realist review highlighted coping strategies as key contexts for feeling able to make and learn from mistakes. The context of student clinical experience developed during development of theories concerning participation in CR tasks (see previous section). This context also seemed to have impact on student ability to cope with making mistakes and engagement in tasks where making a mistake was possible.

Initially, it was theorised that graduate entry students being more mature could be the reason they manage to see the benefit of making mistakes which was confirmed by these graduate entry students.

> "We're not so concerned about ego, protecting ourselves in the same way as some of the undergrads is the impression that I get. So, I am very happy, perhaps slightly too happy, to say I really don't get that, can you just talk me through it, with peers, which I think is a real benefit of being a little bit older and a bit less self-conscious." Student_02_interview

> "I'm 30 this year, and I'm not as afraid of a bad judgement or evaluation of me as I would have been 10 years ago." Student_01_interview

However, more so than maturity or age, students spoke about life experience enabling better acceptance of mistakes to learning. This idea links with experiential learning theory (Kolb, 1984) and the theory of mindset (Dweck, 2012). Specifically, healthcare experience was a key context affiliated

with those students not afraid to make mistakes, value and to learn effectively from them.

> "A little bit of different life experience as well. So, my background has been quite important… I'm a PICU nurse by training." Student_02_interview

> "Sometimes we didn't even get the answers, which was quite, you know, it was fine, if it was appendicitis or whatever else, just the process of going through it." Student_05_interview

> Has made mistakes in process of getting experience. Can be shocking to him, baffling, feels offset…but afterwards felt ok, realised that there is room for variation in the real environment. Student_06_reflection

> Humiliation of getting the answer wrong (making mistake) really helped her understand. This has helped her plan learning for the future too. Student_15_reflection

Having healthcare experience and therefore feeling more confident in the clinical environment has already been mentioned as these students are better prepared to engage with learning in the clinical setting and participate in CR tasks. However, healthcare experience is also accumulated, and teachers noted that confidence to participate, even when a mistake was possible, was more prominent in more senior students.

> "I actually find the medical students by fifth year are quite used to speaking up. They're quite used to getting feedback. They're quite used to being observed." Teacher_04

There is overlap between the confidence that clinical experience provides students and pre-existing self-confidence that enables students to value the benefit of making mistakes to learning. Overall, either clinical experience or a growth mindset enabling appreciation of value of mistakes to learning is required in order that CR is developed from educational interventions where mistakes occur.

Refined CMOC: Learning from mistakes; Student clinical experience or growth mindset

If students have previous clinical experience OR have a growth mindset (C) they appreciate the value (Mresponse) of learning from mistakes (Mresource) and they can reflect on errors constructively (Mresponse) which aids learning and development of CR (O).

Learning about the clinical reasoning process

This resource is very diverse and can be provided by various educational interventions. This may be specific to learning about the cognitive aspects of the CR process explicitly as part of a formal programme or teaching or implicitly through observation of experts and peers reasoning through patients' problems. Similarly, when educators explicitly explain their thought processes to students in a stepwise way this enables students to understand their reasoning. Students also learn about the reasoning process when they receive feedback on their reasoning and performance and when there is discussion and dialogue about patient cases. Students may learn about the reasoning process when they self- explain their thought processes to others, teachers or peers. As with any educational intervention the educational benefit depends on the contexts into which this resource is offered and the mechanisms which are triggered.

Students' clinical domain knowledge

This CMOC was developed from considering the effect of knowledge on students' ability to understand the reasoning processes of experts from observation alone. Originally, adequately high and low clinical domain knowledge were considered as separate contexts, even though knowledge cannot be considered as a binary measurement. Evidence pertaining to each of these contexts relative to the clinical situation were sought and analysed by contrasting educational outcomes dependant on whether the students were deemed to have adequately high or low knowledge for that clinical situation. During this phase of the research, it was clear that medical students are often novices in clinical domains, particularly during their early clinical years. Evidence emerged for contexts of both adequately high and low clinical domain

knowledge and for the potential mechanisms responsible for the educational outcomes as will be described here.

Students who have adequately high levels of clinical domain knowledge relative to the clinical case are likely to be able to observe a clinical encounter and understand the clinicians thought processes sufficiently from the questions that are asking and the patients' responses. This student highlighted that her knowledge from a recent teaching session then enabled understanding of her observation of a ward round.

> "I've had teaching and then I'll go on the ward round, and they'll be talking about certain drugs, or we should do this, and then it makes sense to me because I'm like oh OK, we did that yesterday… because the teaching had been really good beforehand, it was quite straightforward when we were going through it." Student_04_interview

Students also noted that they could learn from observation of their peers in group discussion as their cognitive load would be lowered which would enable them to consider the CR aspects of the case as opposed to when participating in the CR task themselves, they would easily forget salient aspects of the patient history that required further exploration. This would require an adequate clinical domain knowledge of the case under discussion.

> "…those small group sessions were really useful because you would always forget stuff, but you would remember things that other people [had missed].

> When you're watching, you don't have to think about that much…

You're not thinking about the answers as much, you're thinking about the questions other people are asking." Student_03,04_focusgroup

On the other hand, students who had lower clinical domain knowledge often voiced that observation of clinical teachers alone left them feeling confused.

"Which I think to a professional who's done it for years is really obvious, but to a student it's actually not always obvious what's relevant." Student_01_interview

"I just don't know enough about that specialty yet; I don't really necessarily follow hundred percent why they've done things." Student_04_interview

"So many of them [students] when they see the registrar doing this, they don't know why he's doing this…this kind of stuff [routine post-operative review] that they [students] don't actually know why they [doctors] are doing it." Teacher_05

During the realist review phase of the research, theories pertaining to whether clinical teachers would be able to explain their thought processes related to the level of expertise alone. Our theories suggested that peers or near-peers would be better able to explain their thought processes as they were nearer to the student in age and experience. This was supported by some participants.

"…what we're talking about in terms of clinical reasoning and thinking, they [students] are somewhere in the start of that journey, and a consultant has reached a point where, I mean maybe they can't even really explain why they've come to the decision that they've come to. But invariably it's probably the right decision, but they can't maybe unpick all the processes that got them to that point. Whereas someone that's a bit nearer to them is perhaps able to identify with where they're at, but then also help them see, so how did you get to that, just talk me through that and they're probably able to do that." Teacher_07

"…then maybe F1 or the CP3 student would acknowledge that I probably hadn't got that far yet and so they would explain that's why we're going to do the scan because we want to check for this." Student_04_interview

Near peers, these people ask more questions and deliberate in thinking, better able to explain their reasoning. Better able to follow their thought processes, slower and analytical. Student_07_reflection

Peer able to explain their thought process as they had good knowledge, could understand their thought process and reasoning – why they were asking certain questions, the peer was able to explain it at a similar level and that was very helpful. Student_06_reflection

And similarly, participants noted that some expert clinical teachers would not be able to explain their reasoning processes as easily:

"…you might ask someone oh why have you done this and not that, and they give you a really vague answer. And I suspect sometimes that they actually just, they don't know why. They might have a reason why, but it's sort of complex and multifactorial, and they struggle to explain it in a sentence. Or perhaps it's like, it's something they don't want to see. For instance, that's how I've always done it, or it just is." Student_01_interview

"...students will see that [observe clinicians], quite often that provides a big gap to them, and that reasoning feels like a mystery, so they see consultants engaging with clinical reasoning and they think how on earth are we going to do that?" Faculty_04

Consultants quicker, not complete, focus more quickly. Less easy to follow for novice. Student_07_reflection

"I think the more senior you are, the more dismissive you can be of these sorts of things because you use your experience to just say 'oh well, it could be this so let's try this', the students are always going 'well why have they done that, what's the reason behind that'." Teacher_01

Student noted that when their teachers were not able or not willing to explain why they had managed patients in certain ways or come to certain diagnosed this would be a negative learning event.

"Obviously it's a bit demoralising because you'd hope that a doctor would be a little bit better at [explaining]…" Student_03_interview

> "…that would totally depend on who was running that clinic, because people weren't necessarily expecting you…they weren't necessarily there to teach. So, with some of those, they were more the situation where it was just sit and listen. And they were useful to a point, but you didn't go back to a second one." Student_05_interview

> When observe experts consulting with patients, hard for novices to understand their thought processes. Felt annoyed, wasting time and would be more beneficial to study alone to build knowledge. Student_12_reflection

On the other hand, students noted that being able to have opportunity to understand their clinical teachers reasoning processes with feedback on their own reasoning was very educationally valuable.

> "We'd take the history, and then we'd go back to the doctor's room, and we'd discuss the questions we'd asked, their answers and whether or not he would have asked any different questions, or what the sort of answers that the patient gave us, what they were relevant to, and where else we could have gone to with that…That was probably the thing that made it most useful, was the fact that even if you didn't see their full process, you could get an idea of the process that they might use, even if they do it in like a split second. When we're talking about it together and working it out together, they probably slow down quite a lot and share with you, their process. Which I guess is quite useful". Student_05_interview

As data emerged in the realist evaluation, some students noted that certain clinical teachers were better able to explain their thought processes than others and this was unrelated to their seniority but more so to their motivation and time to teach.

> Listening to someone more expert, depends on who it is – some can explain very well, and a level student can understand, some deep in their own expertise and 'it's way over my head', don't trust as much. Expert reasoning too difficult to understand. Student_08_reflection

> "CTFs explain their reasoning…'if patient says this…I'm thinking about this...' It's helpful to listen to someone's reasoning, yeah, they are teaching you how to think." Student_09_interview

> Pre-clinical case studies – stepwise release of information. Expert then would feedback on the case. Most helpful when the expert went through the aspects of the case and explained their thought processes to the students. Student_09_reflection

> Differences between her reasoning and decision making of seniors. Explanations often relate to their experiences so that's why it's correct, causes confusion as difficult to understand their reasoning processes. If they can explain their thought processes, makes it easier to understand. Student_10_reflection

> "If you get a consultant or registrar who's interested in teaching, he may actually stop and say well this is day three of the patient here, this is

what he presented, this is what we are going to do, that's why we're sending this consultation". Teacher_05

Clinical teachers noted that it became harder to explain their thought processes to students as they had become more senior but being in a teaching role enables them, through motivation and time, to practice explaining in a way that students would understand.

When started CTF job, unable to explain thoughts, had become too senior in clinical field but students asking made them relearn how to answer their questions in a way they could understand. Having specific CTFs or people in a teaching role important to enable students can understand. Teacher_01_reflection

"…when you're called upon to explain those decisions, then it can be quite hard because you've based it on perhaps your experience, but actually beyond saying well I've done this before, it's not a great explanation". Teacher_03

"You just pick up the limb because you just pick up the limb and that's what you've been doing for a long time. I think through the process of teaching others it's almost to set me back to be able to articulate it. Because the same question has been asked of me lots of times, then obviously you unpick what you automatically do, and you remember the words or the cues that you've needed to use to explain it to them." Teacher_04

In addition to explanation of their own thought processes, teachers being able to feedback on the student's reasoning processes was also important for their understanding and required teachers with time and motivation to do this.

> Need to discuss the cases with teachers, feedback on the reasoning process and if the management was correct and guidance about what needs to be improved. Immediate feedback required. This was lacking, taking histories is one thing but the discussion is more important to learning. Student_12_reflection

> Researcher: "Do you feel that some students struggle in that situation because they just don't have enough knowledge to think in the same way?"

> Participant: "Could be, especially if you don't have time to explain why you've done that. That could be very possible. He just came and he said that, and I have no clue." Teacher_05

Overall, clinical domain knowledge is crucially important for students' ability to gain from educational interventions that offer the resource of learning about the CR process. These educational interventions could be observation of a clinical teacher in a clinical scenario with a patient, through explanation of their thought processes or through feedback on the student's own CR processes. Students with adequately high clinical domain knowledge, relative to the clinical case, will be able to understand the CR processes of their teachers but for most students, especially if their clinical domain knowledge is lower, a

more detailed explanation will be required to enable understanding which in turn aids CR development.

Refined CMOC: Learning about the clinical reasoning process; Students clinical domain knowledge

If students with low clinical domain knowledge (C) observe experts, they require a motivated teacher (C) with adequate time (C) to explain their thought processes or provide feedback for students to understand (Mresponse) and learn about the clinical reasoning process (Mresource) which then aids development of CR (O). Only students who have adequately high clinical domain knowledge (C) can sufficiently understand expert thought processes (Mresponse) by observation alone in learning about the clinical reasoning process (Mresource), when developing CR (O).

Student self-confidence or student-teacher relationship

The thought processes of clinical teachers may be willingly volunteered when teachers are motivated and enthusiastic. However, the student may need to voice their uncertainty and therefore prompt the explanation they require to aid understanding.

From the realist review findings, self-confidence and self-efficacy were found to be important in enabling students to participate in CR tasks and learn from mistakes, but this context was felt likely to also contribute to other educational interventions. This starting point was used for data gathering in this phase of the research. It emerged that a positive student-teacher relationship

(Tiberius et al., 2002) was another important context and the development of this CMOC will be described in more detail here.

Self-confidence of the individual student was highlighted as a factor enabling or inhibiting students asking questions to correct or further their understanding.

> “Some of them are a bit shy, they may feel a bit intimidated in speaking up.” Faculty_01

> “I feel like I’m confident enough to be now to sort of say ‘hang on I didn’t quite understand - how did you get there?’ I think if I felt like I had no idea what was going on I would probably ask.” Student_02_interview

> “I definitely think that the whole medical education in a way, it's kind of geared towards extravert students that are willing to put their hands up and ask questions. I think I've changed a lot since the beginning to now in terms of just thinking and if I want to be a safe, good doctor by the end, I'm going to have to just start asking and being a bit more pushy.” Student_04_interview

> “Some people will naturally always ask questions if they’re unsure and that’s very easy to deal with.” Teacher_03

As has been noted in previous CMOCs the experience of the student, specifically previous clinical or healthcare experience is an important factor for determining effectiveness of many educational interventions. In this student’s

case, previous healthcare experience, contributed to her confidence in being able to talk to teachers and ask questions.

> Used to talking to fellow health care professionals as has healthcare experience, so better able to talk to clinical teachers, feels comfortable in conversation. Understands she will learn more if she's comfortable with her teachers. Student_13_reflection

Students also noted that questioning which led to discussion was more valuable than just listening to an explanation alone or observing, but this requires student self-confidence.

> Discussion most helpful to learning to clarify rather than just listening to the reasoning explanation or observing. Will tell herself she should know, and she doesn't so wouldn't feel able to ask questions, easy to compare to others in the group but the reality is sometimes no one understands, and no one asks questions. Student_10_reflection

Students noted that not all clinical teachers were motivated or willing to volunteer explanations of their reasoning processes or why patients had been managed in certain ways, but this could be overcome by asking provided the student felt confident to do so.

> "I think you'd have to ask some of them. I was always quite happy at the end to ask. And usually, even if they weren't particularly, you could tell they weren't particularly up for teaching, they'd usually explain what was happening, even if they weren't going into loads of detail." Student_05_interview

> You mainly have to ask to get this explanation, students who are confident and happy to speak might be more likely to these explanations. Might not always be offered. Not all students do that and then experiences vary. Main factor is confidence. Student_07_reflection

> "If people [students] have the confidence to ask a question, people will generally do their best to answer them and give them a good explanation. But it probably is a little bit incumbent on the students to actually ask." Teacher_03

It was mentioned by some participants that near-peer teachers may be better situated to enable students to ask questions and have discussion.

> Participant: "…there's a little bit of a difference between consultant and the teaching fellow and then the students, so the students may find it a little bit easier to share maybe their experiences or interact."

> Researcher: "Why do you think that's the case?"

> Participant: "Well because I don't think they feel that intimidated. I don't think I come across as very intimidating, but they might get the consultants who may come across as intimidating or might come across as very senior, so they may feel that ease of sharing or talking about things." Faculty_01

> “The teaching fellows that I’ve had have all been really excellent, and I think are the people that I’ve learned the most from, both in specific teaching stuff, specific concrete knowledge, but also reasoning. They’re the people you feel are the most available to ask questions of all kinds to.” Student_01_interview

However, more so than the level of experience, many participants highlighted the relationship between the student and teacher was more important and this was facilitated by clinical teachers being approachable, putting students at ease and creating a safe environment.

> “…building up a rapport with somebody. So, there isn’t this sort of barrier of consultant-student…it allows a student if they do have problems to say, ‘I’ve got a problem here’. I think that’s one of the problems that students aren’t sometimes able to say I’ve got a problem with this area of teaching.” Faculty_02

> If teachers able to make her feel at ease and more likely to engage. Student_11_reflection

> Might feel more confident when felt comfortable with people, virtual environment and felt comfortable and good rapport with the teacher. If teacher seemed stricter, might not volunteer. Doesn’t matter if near-peer or senior doctor, more related to relationship with them, impression of them rather than seniority. Teachers that put you at ease, may aid confidence. Student_09_reflection

> "I'm with them for two weeks, I can build a rapport with them. We felt it's a safe environment to ask a question and answer a question. They do like to challenge me with questions about 'why did you say that, is there any particular reason why the answer is this or that?'" Teacher_05

This participant noted that building a safe learning environment was part of the building of a relationship between the student and teacher. This context was also seen prominently when learning from mistakes was offered as an educational resource.

> Participant: "…if we create a safe environment, we've got students who ask a lot more, who then say 'well OK, can I ask why you came up with this and not this?'"
>
> Researcher: "So develop more of a relationship with those people and they feel more comfortable presumably then to ask those questions?"
>
> Participant: "Completely." Faculty_05

Overall, a student's self-confidence enables them to ask questions of their clinical teachers when they are unable to understand the CR process. In addition, a developed student-teacher relationship puts the student at ease and feel confident to ask questions. Both contexts are important for the development of CR through the mechanism of learning about the CR process through understanding and consolidation of knowledge.

Refined CMOC: Learning about the clinical reasoning process; Student self-confidence or student-teacher relationship

Students who have good self-confidence (C) or who have a good relationship with their clinical teachers (C) are more likely to feel confident to ask questions (Mresponse) as they feel at ease (Mresponse). This enables learning about the clinical reasoning process (Mresource) through understanding and consolidation of knowledge (Mresponse) and a positive impact on CR development (O).

Acknowledging the importance of clinical reasoning

It was recognised from the realist review that knowing about the cognitive aspects of decision making or being advised to try and avoid cognitive biases by employing analytical reasoning, was not effective in reducing diagnostic error or improving CR. However, during this phase of the research, many participants noted the benefits of understanding about the CR process. This perhaps did not help them 'in the moment' but aided in reflection which is known to assist CR development (Mamede and Schmidt, 2022). The development of this CMOC is discussed here.

Faculty members noted that it was important for students to be informed about the processes of CR as it can become lost in the curriculum which can mean that for some students, the importance of CR is under-emphasized.

> "[CR] is woven into the process of the curriculum rather than, 'ah now we're reasoning, or this is the context in which we reason'. Yeah, it has to be ubiquitous. And sometimes it can't because in those settings it's not that visible. So, it's something that's so well integrated students don't know they're doing it. So, we do need to have points where it becomes more visible." Faculty_04

In Nottingham, the graduate entry (GEM) students were delivered formal teaching on CR processes in their pre-clinical years. However, the undergraduate course, at the time of this research, did not incorporate a CR course for all students which was highlighted as a weakness.

> BMedSci in decision aids and clinical decision making, this has advanced her understanding of clinical reasoning and believe this is different to other people in her year as she didn't know nearly as much as she does now. Not explicitly taught in the medical curricula. Student_10_reflection

> Never taught about CR or the importance of it. Never taught about it. Student_12_reflection

Students noted that understanding about the process of CR was important but perhaps the teaching needs to be repeated and reinforced throughout medical training to ensure that it is relevant to students' needs and stage of training.

"I think we need to think about the series of reasoning, understanding how that integrates around clinical method, clinical skills, thinking about their point of, the point that they are on the journey." Faculty_04

"…we have this session in GEM, about different kinds of bias and I wish that we would do that again as I found that so helpful but the only one I can remember is confirmation but there's lots of different kinds. Just having that brought to the forefront at this point [clinical phase] would be really useful." Student_03_focusgroup

This student has read about reasoning themselves rather than being taught. Prompted to learn about this after CP3 medicine teaching. Before this, more focussed on going to activities. If it were taught, might act as a prompt to help understanding within themselves. Likely to be more beneficial later in the course. Student_07_reflection

If students were aware of CR processes during the interviews the researcher endeavoured to discover what it was about this knowledge that aided CR development. Some students noted that knowing about CR processes was useful, not so much for during CR tasks but afterwards when reflecting on their performance.

"…when I think about it afterwards again, I use those kinds of contexts of biases and processes of reasoning to think about what I might have done differently. I don't think it's very often that when the actual, when there's an actual patient in front of me, oh what are the processes that I'm using? It tends to be more of like reflecting." Student_01_interview

However, some students noted that an awareness of bias reminded them to not latch onto one diagnosis and ensure they kept an open mind.

> "…if you're taking a history and then that leads you automatically to one diagnosis just being conscious of bias I think and having that sort of, well hang on a second, sort of pull back a little bit and then like go broad. I find that so helpful. And that's really important to me, I think. I wish we'd talked about it more." Student_02_interview

> Being told keeping an open mind, not narrowing etc. – rules of reasoning – this has changed his reasoning in subsequent cases, and it does occur to think about what is missing or what not to miss. Student_14_reflection

This feeling was shared by another student participant who noted that there might be some impact on making an error during information gathering.

> Researcher: "What is it about knowing about your thought processes that's actually helpful?"

> Participant: "Just, it can stop you going down the wrong path. And it can help you ask, if you're aware of your thought process it can help you to ask questions that you on the spot might not think are important, but then when you think about the bigger picture or what you might be missing, you can then, if you go in thinking about what you may or may not be omitting, and you're aware of that before you're asking questions, then it might stop you not asking the questions that you

might need to ask. I think it's always useful to remind yourself that you may be wrong, your gut instincts may be wrong." Student_05_interview

The idea that ensuring students remind themselves they might be incorrect is likely to be particularly beneficial when they have a lower knowledge of the clinical domain, which is often the case for medical students when they are novices in clinical areas. As clinical domain knowledge improves, their non-analytical thought processes are more likely to be correct. Ensuring metacognitive control (Croskerry, 2018) over decisions is an important part of not making an error and, in addition, a valuable trait in CR development. Overall, being able to reflect during or after a CR task of educational encounter was felt to be mechanism responsible for CR development.

Refined CMOC: Learning about the clinical reasoning process; Acknowledging the importance of clinical reasoning

When medical schools acknowledge the importance of clinical reasoning (C) and students learn about various aspects of reasoning processes (Mresource) through explicitly incorporated teaching about the cognitive aspects of human reasoning and clinical reasoning, this enables better reflection on reasoning (Mresponse) during and after participation in CR tasks and a positive effect on CR development (O).

Teacher motivation and time to teach

This CMOC developed from the CMOC derived from the realist review which stated:

When teachers have a good subject domain knowledge, or they are closer to the student in age or medical level (near peer) (Context) they are better able to explain their thought processes (Mresource) which is better understood by the students (Mresponse) as their thoughts are more congruent (Mresponse) which leads to better CR development (Outcome).

During the realist review, being a near peer teacher was felt to be a mechanism which enabled student understanding through reasoning processes being cognitively congruent. However, through the realist evaluation and as the researcher's realist understanding developed, it was felt that being a near peer teacher was probably part of the intervention and the explanation they offer is a mechanism - resource.

In the realist interviews, evidence was gathered for this CMOC and was corroborated by some participants.

Participant: "…it would be the F1 or the CP3 that would be explaining why they were doing things, which I think may have been just very obvious to a consultant, but then maybe F1 or the CP3 student would acknowledge that I probably hadn't got that far yet and so they would explain that's why we're going to do the scan because we want to check for this. I would be like OK thank you."

Researcher: "Would they volunteer that to you often?"

Participant: “Yeah, often.”

Researcher: “Without you having to ask?”

Participant: “Without me asking, yeah. Well, it was much more likely that they would offer it than say the consultant if they were busy.” Student_04_interview

The lower grades of medical staff seemed to appreciate more that the students may not follow what was going on in ward rounds and this would prompt some doctors to offer this explanation to the students. Participant (Student_04) offered an explanation that the consultant may not have had time to explain as the student perceived they were too busy. However, the same participant also noted the following…

“Some of the consultants have been fantastic and some of the registrars and things have been really good at explaining case-by-case. But just anecdotally it seems to be the people that are closer to where you are maybe have a bit more of an idea of what your level is, maybe.” Student_04_Interview

Throughout other interviews, although not recordable in neat quotes, there was a feeling that more senior people forget how basic students’ understanding is, but peers have a better understanding of the ‘right level’. Student_08_reflection

Despite these students' experience that near-peer teachers seemed to be better at explaining, there was emerging evidence that specific consultants and senior doctors were good at explaining their thoughts to the students. Evidence was therefore sought about what could explain the difference. An idea was developed that interest in teaching was the most important factor in whether teachers took the time and effort to explain their thought processes. This participant highlights this by mentioning a teaching fellow, who is inferred to be interested in teaching by virtue they have taken a specific teaching job compared to other equivalent level doctors who are not in teaching roles.

> "I had my A&E placements, there was a teaching fellow that took us, and she was fantastic. Whereas some of the senior regs that maybe aren't interested in teaching, especially in an acute setting, were very much like not going to involve you at all." Student_04_interview

Motivation to teach was supported by other participants:

> "…students that struggle will ultimately need more one-to-one face-to-face contact with their tutors. It comes down to [teacher] self-motivation. What we don't want is people [students] who are bad going off and doing lots of practice and reinforcing their bad habits, and somebody has to supervise them." Faculty_02

This participant, a faculty member states that teachers have to be self-motivated to supervise students and correct 'bad habits'. This highlighted the importance of motivation in teachers as well as interest in teaching. The idea that motivated teachers were required for good teaching was further highlighted by this faculty member.

> "…ultimately if you put a student and an enthusiastic clinician and a patient in a room and it will be a positive experience for the student, and they will benefit from it." Faculty_04

The researcher's reflections from interviews with experiences that students' participants S10 and S11 had with explanations from more senior doctors, consultants and experts revealed the following:

> Some experts can explain their reasoning much better, teacher was calm, took the time and authority. Obviously very interested in education, motivated to teach, regardless of seniority, interest in teaching enables teachers to explain their reasoning processes to undergraduates. Student_10_reflection

> Discussion followed seeing patients, asked more questions and what examinations would be helpful. Clear explanation from GP about case and potential diagnoses, [Teacher] obviously motivated and engaged. Student_11_reflection

However, sometimes motivation to teach was insufficient to ensure students gained understanding and knowledge acquisition, clarification, and refinement; time was also an important factor.

> "I think the biggest thing is probably creating time for those discussions to happen, and I think time is probably the biggest challenge more than

anything else, within the competing constraints, with all of the other competing things going on." Teacher_03

This participant suggested that seniority was associated with less time. Senior members of medical staff were sometimes portrayed as less able to explain their thoughts to students, but in fact a lack of time was the most important contributor.

"…actually, the more senior you are generally the busier you are, and the more constraints you have on your time." Teacher_03

Students also noted the effect of time on teachers' ability to explain their thoughts.

"…sometimes it would be going out of their way when they're already in a busy clinic or whatever. And I think that would stop some doctors when they've got medical students with them doing extra things, because they are quite time pressured." Student_05_interview

"I definitely notice that there's just not as much time to involve you. And maybe at the beginning they'll be engaged, but then as the ward round comes on and it gets busier and busier, they'll drop off a little bit. So, I definitely think some of the busier wards, it's more difficult." Student_04_interview

Faculty members also acknowledged the importance of time:

"…depends on individuals and how rushed consultants or registrars or whoever else in the clinic." Faculty_01

From a starting point of near-peer and proximity to training level as being the most important contexts, motivation and time to teach became the prominent contexts in this CMOC determining whether adequate and understandable explanation to the student would occur.

Revised CMOC: Learning about the reasoning process; teacher motivation and time to teach

Motivated clinical teachers AND those who have time to teach (C) give immediate feedback and have discussion with students, enabling learning about the reasoning process (Mresource) through acquisition, consolidation, clarification and refinement of knowledge (Mresponse) and understanding (Mresponse) which has a positive impact on CR development (O).

Student adequate self-confidence, clinical domain knowledge, experience, and uncertainty tolerance

In addition to the educational interventions that enable learning about CR such as feedback, discussion and explicit teaching about CR processes, educational interventions and CR tasks in real clinical practice often incorporate patient cases where the diagnosis is unclear or the presentation unusual. These cases highlight uncertainty, ambiguity and complexity and are commonplace in

medical practice. This CMOC theory emerged from the evidence during the realist evaluation as described here.

Teachers noted that uncertainty and complexity in the clinical environment was commonplace.

> "I think that's a really hard thing for students to appreciate this uncertainty or the inconsistences from one practice to another, they assume there is the same answer for every patient and every patient presents the same way and actually, take them out of that and it is a bit earth shattering for them at the beginning where they realise that, you know, they've been taught over years that things are quite linear and binary and then actually they [realise] it's a balance of probabilities and what do it think is going on here and maybe a trial of this and it's inherently uncertain and ambiguous world." Teacher_01

Teachers also noted that educational and assessment practices suggest that there is a diagnosis or single best answer to be found and that introducing them to the reality of uncertainty in clinical practice could be helpful for CR development.

> "I think the ward skills things for example are quite staged, and the OSCEs are quite staged, so the patients behave in a nice, neat way which doesn't happen in life. You'll say a particular pathology has three or four signs, and then your patient will have two of those and something else completely different, but they have that pathology, if that makes sense. So, they don't fit that neat box quite as nicely as what we teach them,

so I think more ad hoc clinical teaching, less structured would be helpful." Teacher_04

When considering when teachers would contemplate introducing uncertainty and complexity to students, most agreed they would not introduce uncertain cases to novices who are yet to master the basics of CR. Teacher_02 suggesting that they would only introduce more complex cases to students in their final year, highlighting that experience is valued as an importance factor for students to be able to tolerate uncertainty and complex cases. Some teachers suggested they would not introduce very complex patients to any students as these cases do not help them meet the curriculum requirements.

Participant: "The very complex patients that you don't have any clue what's going on with them like the investigations or the impression would be oh could be this, could be that, could be that; partly because my placement is short, and I want to target my learning towards really something beneficial, and partly because students don't like these cases as well, although it's real."

Researcher: "Why is that?"

Participant: "Because they always want an answer as well."

Researcher: "Why do you think they always want an answer?"

Participant: "Because that's what we direct them in the curriculum." Teacher_02

Similarly, it was noted that students would not appreciate cases where there was uncertainty due to a perception that assessments are looking for one correct answer.

> "I think there is a fear that those assessments are more, the answers that examiners are looking for in those assessments are more black and white than actually they are. So, I think you're right that it is, it's driven by a fear of failure, and therefore to some extent they want to know what the best answer in an exam is." Teacher_03

When assessments were imminent, students noted that they would be less inclined to engage with uncertain or complex cases due to a perception that these cases will not help them pass the examinations. This may also affect engagement in clinical environments more generally as clinical cases are frequently ambiguous, uncertain and complex.

> "I think at this time of the year when exams aren't very close, I would be think, if it makes me a better doctor then it's all very good [going to the wards and clinical settings] but I suspect a few months down the line when exams are looming then I would think that's not going to help me pass the exam, and it's not going to help me learn all the text book objectives we need to know, I would prioritise things that I think would help me pass the exam which is sad but maybe the way it is." Student_02_focusgroup

In addition, self-confidence was noted to be an important factor in whether students would engage in tasks that were more uncertain and complex.

> Researcher: “Do you think that fear of thinking that there should be a right answer is going to prohibit students from engaging then in a process that is actually teaching them something that’s more complex?”

> Participant: “Maybe it does up to a point. I’d like to think that it wouldn’t, but I suspect that it is inevitable that some are, certainly for the less confident students.” Teacher_03

Students noted that uncertainty was not often part of educational processes throughout medical school and that often, clinical teachers did not voice their uncertainty although this would be helpful. This student also voiced that assessments do not feature uncertainty in diagnosis which leads to a disparity between the implicit requirements of the medical degree and what the students are likely to encounter regularly in clinical practice.

> Uncertainty in CR, this isn’t dealt with well in simulations as clear diagnosis. Better to appreciate this in real life scenarios. In early stage of medical school, you think there should be an answer, even in later stages, the exams are focused on there being a correct answer. Should be reinforced, might be helpful for doctors to discuss their own uncertainty in their differential diagnoses. Student_14_reflection

Overall, student experience and confidence determined how they might respond to various educational interventions which introduced uncertainty or

complex cases. When medical school examinations were close, students would be less inclined to engage in these tasks due to a perception that they would not help them pass the exams even if they appreciated uncertainty was common and it would aid their CR development in the longer term.

Revised CMOC: Learning about the reasoning process; Student adequate self-confidence, clinical domain knowledge, experience, and uncertainty tolerance

When students have adequately high and appropriate levels of self-confidence and experience (C) they are ready to learn about more complex aspects of the clinical reasoning process (Mresource) such as the uncertainty, ambiguity and complexity of real-life situations which deepens understanding (Mresponse) and is useful to the development of CR (O).

When students have lower self-confidence or experience (C) or when examinations are imminent (C), exposure to complex aspects of the clinical reasoning process (Mresource) may cause confusion and fear (Mresponse) or a perception these educational experiences will not help them pass the assessments (Mresponse) which may reduce engagement in the clinical environment (Mresponse), reducing opportunities for CR development (O).

Encouraging analytical or non-analytical reasoning

As students become more experienced, they will use their knowledge to engage in non-analytical reasoning without being prompted and, with practice, these initial hunches will guide the students questioning during data gathering. There is only so much therefore that non-analytical reasoning can be encouraged as it develops naturally with developing ability and skill in CR. Educators may be able to aid students in their realisation that non-analytical reasoning is developing and enable students to trust this form of reasoning as being accurate when sufficient domain knowledge is acquired.

Analytical reasoning can be encouraged by guidance through clinical problems and encouraging students to explain their reasoning processes. These principles can be applied to a range of different educational interventions. The following CMOCs represent the development of theory where the resource offered by the educational intervention is encouragement of analytical or non-analytical reasoning.

Student low clinical domain knowledge or self-confidence, motivated teachers, and analytical reasoning

The results of the realist review noted that low clinical domain knowledge was a key context in determining the effectiveness of many educational activities. With respect to encouragement of analytical and non-analytical CR, the realist review found that encouragement of both types of reasoning and activities that encouraged analytical reasoning alone, were effective in aiding CR development. This starting point was built further upon during this phase of the research.

Student participants noted that when teachers aided them through gathering of information through questioning why they had asked certain questions and what they should ask next, this was useful in developing their history taking and CR skills.

> "I think making it, supporting us to do it more by slowing it down and getting us to do histories but then maybe pause the history saying 'right, have a moment to gather your thoughts, what have you realised so far?' and encouraging us to think about what we know, what we can rule out or in and once the student gives that answer you could say, 'what questions do you now think you need to ask to rule those out or in?' so maybe helping us to take a structured history." Student_01_focusgroup

> "…he would be why have you picked up on that and what do you think that could be? And then the next person would do the next part. And that was always probably the more useful ward teaching that I've had." Student_04_interview

> Teaching can encourage CR by asking questions about their reasoning process, encouraging them to think about other things. Asking not only the what questions but also the why. Student_14_reflection

These quotes suggested the mechanism responses of understanding and of clarification, reinforcement, refinement of knowledge, both of which contribute positively to development of CR. The mechanism of understanding was observed by teachers as being an aim of teaching in the development of CR.

> "…to tease out not only did you do it well, but did you understand what you were doing as well." Faculty_03

Faculty participants highlighted the importance of reasoning in a structured, analytical way when students are novices, in this case, to the clinical area of dermatology:

> "…all the while they have to be thinking about more of a stepwise, logical process rather than just this is the answer. Approach, yeah, absolutely. Because the reason is that you may get it completely wrong just because you're basing your assumptions. And that can be dangerous because the knowledge is limited." Faculty_02

Clinical teachers also highlighted that they aimed to encourage this structured approach, particularly for very junior medical students or those with low clinical domain knowledge:

> "…rather than just let them run through it and then pick out the things that were wrong as such, I was very much involved in the scenarios. So, I would stop them and say so let's just take a pause, so what do you think is going on at the moment? Do you think your patient is responding to that, or do you think you might want to think about something different? Rather than let them run through the whole thing, and then pull it apart. And I got some really nice feedback from the students about, I guess about my teaching, that it was really interactive. That it didn't feel threatening, that they felt able to explore the scenario, rather than feel like there was a right or wrong. Which I think

worked well for them, because they were CP1s, so they're just about to start their clinical phases." Teacher_07

"…you asked me before if they're novices, and I think in this context, I think because they are, I think from what I understand about principles of teaching, they tend to think in that stepwise way. So, I try to break it down rather than, because it does approach that I would, almost automatically know that those injuries are vulnerable to those particular injuries, particular nerves are vulnerable in particular injuries. So rather than just knowing, I think for me I learn something better if I understand it." Teacher_04

Teachers noted that students who lack self-confidence also benefit from a structured and guided approach to CR.

"I think you can definitely see the students that lack confidence. And that's where for the CP1s that more of a discussion based leading them through the scenario works really well for them." Teacher_07

"…others that are less able or looking to you for prompting. Sometimes I ask them to rate their confidence before we go in on a scale of one to 10, so things like that. So, if they score themselves as less confident, I almost, not hand hold them through, but just guide them through a little bit more." Teacher_04

It was clear that teachers and students both appreciated the importance of encouragement of analytical reasoning when students had lower clinical domain knowledge or self-confidence in particular clinical scenarios. In

addition to what was already known from the realist review, an additional context that was highlighted was teacher motivation. Without motivation to teach, the teacher may not give so much support to novice students (Researcher_reflection). This context was inferred from the data set as a whole, describing teachers who specifically gave time to teach students and asked lots of questions or guided students in order that they would have a deeper understanding of the clinical area. This motivation would either be intrinsic, for example, the clinician had a love of teaching and found pleasure in teaching or an extrinsic motivation, for example, the clinician was in an employed teaching role. For many clinical teachers, motivation is both intrinsic and extrinsic as many clinicians seek out roles that they hold a passion for.

Virtual patients and the use of virtual case scenarios were used more frequently following the impact of the Covid-19 pandemic prompting social distancing. These virtual educational interventions were highlighted by some students as allowing development of CR through promotion of analytical reasoning. These cases were designed by motivated, clinical teachers and it is likely they understood the most effective way of delivering the information to students who, overall, had a lower clinical domain knowledge since their clinical experiences and teaching was curtailed by the pandemic.

> Sequential release of information in cases and generic lectures on cases. (Clinical reasoning case online), able to go at own pace, think for yourself, actively recall information. Student_08_reflection

> Virtual cases – encourage first impressions and then encouraged to use analytical thought. Structure helpful to novices and aids insecurity. Provides a scaffold to reason with. Student_10_reflection

Overall, motivated teachers are required to support those students with lower clinical domain knowledge or self-confidence and encourage analytical reasoning through various educational interventions including prompting, scaffolding, and encouraging explanation of the students' reasoning processes.

Revised CMOC: Encouraging analytical reasoning; student low clinical domain knowledge or self-confidence and motivated teachers

If students with low clinical domain knowledge (C) or low self-confidence (C) are supported by motivated teachers (C) through the clinical reasoning process with scaffolding and prompts, analytical reasoning is encouraged (Mresource) which promotes understanding (Mresponse) and clarification, reinforcement, refinement of knowledge (Mresponse) which all have a positive impact on CR development (O).

Student low clinical domain knowledge and non-analytical reasoning

The realist review found that when time pressure was induced to encourage non-analytical reasoning, this had a detrimental effect in students with lower clinical domain knowledge. This was further explored in the realist evaluation to see whether this CMOC could be confirmed, refuted or refined.

In contrast with what could be expected of an expert's decision making, students were aware of their lack of knowledge in certain clinical areas.

> "I think to a professional who's done it for years is really obvious, but to a student it's actually not always obvious what's relevant." Student_01_interview

> "I think it's been encouraged…to use your gut in a way, but never trust it. Have it there as a good guide, but also be quite aware that it could be wrong, especially when you've not seen enough for your pattern recognition to be that finely tuned" Student_05_interview

Both clinical teachers and students alike alluded that encouraging non-analytical reasoning alone felt dangerous, unsafe, and not the most effective way of teaching to develop CR.

> "…you may get it completely wrong just because you're basing your assumptions…and that can be dangerous because the knowledge is limited." Faculty_01

> "…it's really dangerous for me just to say this is BPPV, and it's caused by crystals in the inner ear, and they don't know what BPPV is." Teacher_05

> Consultant in CP1, often ask spot diagnosis, or what can you tell from certain situations. Initially terrifying, especially in CP1, as don't know anything, no concrete information to go on. Student_15_reflection

There was very little data suggesting that a time pressure applied purposefully to induce non-analytical reasoning was a technique employed by

clinical teachers in this research. This may be because students are often presumed to be novices and there is an awareness that their non-analytical reasoning is therefore likely to be incorrect. One student (Student_14) noted that a time pressure could be helpful to learn how to manage emergency situations but also noted that it wouldn't be helpful in niche or obscure situations suggesting that clinical domain knowledge would need to be adequate to find this activity educationally valuable. Another (student_13) noted that time pressured situations cause nervousness and embarrassment and only work when clinical domain knowledge is higher.

Overall, the CMOC developed in the realist review has been confirmed through data gathered in the realist evaluation. The data suggests that encouragement of non-analytical reasoning alone through various educational activities, including the application of time pressure, is not useful to CR development as it feels unsafe and causes confusion in students with lower clinical domain knowledge. This was deemed to have a reduced impact on CR development compared with other potential educational interventions.

Revised CMOC: Encouraging non-analytical reasoning; student low clinical domain knowledge

If students with low clinical domain knowledge (C) are encouraged to use non-analytical reasoning (Mresource) including through application of a time pressure in teaching, this leads to confusion (Mresponse), doesn't feel safe (Mresponse) and is likely to lead to a reduced impact on CR development (O).

Motivated teachers, student-teacher relationship, and non-analytical reasoning

This CMOC emerged from pre-existing understanding that teacher motivation was needed for successful implementation of many interventions to develop CR, and that the student-teacher relationship had emerged in the refinement of other CMOCs. The realist review found that non-analytical reasoning occurred in students with higher clinical domain knowledge and therefore encouraging analytical reasoning in this group could lead to frustration.

> *When students with high clinical domain-specific knowledge (C) are instructed to use analytical reasoning alone or this is promoted by ensuring they think through all aspects of the case (Mresource), they may feel frustrated (Mresponse) as they can rely on non-analytical reasoning (Mresponse) and still attain high diagnostic accuracy (O).*

This CMOC did not consider however whether encouraging non-analytical reasoning alone would be useful to the development of CR or what the other contexts affecting this resource would be which was further explored in this phase of the research.

Clinical teacher 02 (teacher_02) noted that they felt building a relationship with students was important and it would be easier to assess their level of knowledge when they knew students better. This would translate into knowing when they needed to ask for more information about a clinical case and when trusting the student's initial judgement would be appropriate.

Researcher: “You’re trying to gauge where they’re at?”

Participant: “That’s it yeah.”

Researcher: “So, their knowledge level.”

Participant: “Yeah.”

Researcher: “And if you feel that they’re towards the higher end, then you’re less likely to go through that stepwise approach?”

Participant: “Exactly, yeah.” Teacher_02

“…only if I feel comfortable that the students have a good background in something, then I would not go through the whole gamut from start to finish.” Teacher_02

One faculty participant highlighted the student-teacher relationship as a context. Although the teacher was motivated, lack of continuity in the clinical placement was a significant barrier to assessing progression and understanding the students’ requirements:

“I would love to see my students four or five times in clinic, getting them to take histories and see them progress, but the nature of the course is

> that you don't get to see them like that. There isn't that progression…how you set up a teaching programme for undergraduates so that you can see progression? ...I don't think we do that. I couldn't tell you any students that I can, have sat through their eight weeks with us and know what they were really like on day one and what they were like at the end of it. There are a few that have come to clinic on a regular basis and theatre who you've interacted with. But some of the students it is just a fleeting hello, I've come to your clinic, I will clerk five patients and you don't see them again. Which I think is a bit sad." Faculty_02

In some clinical placements, such as primary care, there is more continuity between the student and their clinical teacher which enables building an understanding of the student's knowledge. This allows the teacher to assess whether the student can be trusted to act independently or if this requires closer supervision.

> "…the clinicians who are confident in a student who they've sat with, and they take a history, and they present the history and the primary care clinicians will trust that history or will they re-go over it again." Faculty_04

But it was noted that the current educational placements do not allow this relationship to develop, this faculty participant suggesting this was related to a constrained and limited exposure with a single educator.

> "…at the moment students aren't able, aren't given the opportunity to demonstrate to working clinicians exactly what they can do because their exposure is so tight, so constrained." Faculty_04

Medical students identified that they had a part to play in building that relationship, indicating that attendance in the clinical environment would potentially translate into more learning opportunities if educators saw the students were willing. Although with regular staff changes, there is no guarantee of regularly seeing the same clinical educators in the clinical environments.

> "If you're a medical student and you turn up for one ward round and then not again and they don't see you, maybe they spend more time with you if they see that you're investing a bit of time on the ward as well." Student_02_interview

Students noted that if they were welcomed into the clinical environment and had a regular ward where the staff knew the students, this resulted in a more positive experience and better student-teacher relationships.

> "I've been on healthcare of the elderly for two-and-a-half weeks, and I've only really been on the ward a handful of times, and I think that's difficult because staff don't recognise you; whereas, at [X hospital] they had a brilliant experience at CP1 because they were assigned to a ward for eight weeks and everyone was so enthusiastic." Student_04_interview

These data highlight the value in students having continuity in clinical placements in order that staff know them and can build a relationship. This is

likely to have lots of positive benefits to the students but for the purpose of this research, this is likely to have a positive effect on the development of CR.

> Thinking quickly, time pressure induced artificially, stress of clinical deterioration – explored NAR, may happen as spot diagnosis, quickly answering question. At the time may be stressful but educationally valuable as more likely to remember. Experience of being put on the spot, educationally valuable. If obscure fact, or niche, wouldn't find it so helpful. Student_14_reflection

> Has been asked quickly for a diagnosis – intuitively decide what the problem. Yes helpful, remember it better when being asked…and put on the spot, element of nervousness and embarrassment, probably would only work if you had a good knowledge base. Student_13_reflection

These students identified that certain educational activities promote NAR, either artificially through a time pressure or through being asked quickly for the diagnosis of a patient from the provided information. Both students found this helpful but identified that good knowledge of the clinical domain was a pre-requisite, again highlighting that in those situations where students' knowledge can be adequately assessed, teachers are better able to identify those students likely to benefit from promoting NAR.

The mechanisms of how promotion of NAR would aid CR development was inferred from these data. Students suggested that being put on the spot could be stressful, embarrassing or cause nervousness. These emotional responses in the context of a student with good clinical domain knowledge who

is likely to get the correct answer, were inferred to allow the student to feel more confident that their CR ability is developing.

Overall, when teachers are both motivated and able to build a relationship with students, this enables them to better assess students' knowledge and allow students to naturally use non-analytical reasoning when teachers assess they have a sufficient knowledge within that clinical domain. Various educational techniques may be employed to encourage NAR in this group of students. Students gain confidence and appreciate that their CR ability is developing.

Revised CMOC: Encouraging non-analytical reasoning; motivated teachers and student-teacher relationship

If motivated clinical teachers (C) are able to spend extended periods of time with individual students and form a relationship with them (C) they are better able to form judgements about their knowledge and ability (Mresponse - teacher) which allows teachers to appropriately allow or encourage students to use non-analytical reasoning (Mresource) when students are deemed to have appropriately high knowledge (C) which builds confidence in students (Mresponse), allows them to appreciate their CR is developing (Mresponse) and has a positive effect on CR development (O).

Adequate clinical domain knowledge and encouraging both analytical and non-analytical reasoning

In this CMOC, encouragement of using both forms of reasoning were considered. From the realist review, the CMOC which was primarily being refined was as follows:

> *When students with low clinical domain-specific knowledge (C) are instructed to use both non-analytical (or pattern recognition) and analytical reasoning (or reasoning in a stepwise approach) (Mresource), they are empowered to trust their developing sense of familiarity (Mresponse) and developing ability (Mresponse) which results in an increase in diagnostic accuracy and learning gains (O).*

During the early part of the realist evaluation, it became clear that those students with low clinical domain knowledge are unlikely to use NAR, even if they are encouraged, as this form of reasoning occurs naturally with developing knowledge and experience. It is, therefore, impossible to force students to use NAR directly although it may be encouraged provided adequate clinical domain knowledge is present. For some student's guidance towards using NAR was invaluable in their CR development as noted by these students…

> "…when I first started, I didn't have a clue what I was asking and what I should be asking. It wasn't until maybe CP1, or when I had the first teaching session with [the O&G teaching fellow], because I think you said when you first hear the presenting complaint, you need to think of 3 things it could be and choose your questions to eliminate or not eliminate each one… and I thought 'why haven't I been doing that?' and

I think someone should just sit everyone down and tell them that." Student_01_focusgroup

"We had a lecture from a respiratory physician in Derby who was like, you need to check the timeframe and another 3 symptoms and then you should be able to have a diagnosis and having it done like that, makes you pull your boots up a little bit, instead of searching for the questions to fill the space you would go 'right so actually…' and it sort of focusses the mind." Student_04_focusgroup

This faculty participant was asked whether they would encourage all students to take a very focused approach to assessing a patient.

"Not at the beginning I wouldn't because I think it's very important to take a broad view. The question is when do you start to try and focus it down? When can you safely do so? And that's probably not, or I'm not aware of a very clear answer to that." Faculty_03

They highlighted that students at the beginning of their medical training would not be expected to focus down. Gaining knowledge and experience is important to be able to make an accurate assessment and, until then, a stepwise approach would be encouraged, as previously noted. This participant did suggest that by the time students get to CP3 (final year) they would be expected to be able to focus on the clinical problem and work within a time constraint where a degree of non-analytical reasoning is likely to be required.

Clinical teacher participants were helpful in refining this CMOC as they noted that despite the student's experience or knowledge, they would likely

always get a student to think though the cases in detail at some point in the teaching encounter.

> "…the ones that I've highlighted I think that are actually really able, and you've demonstrated to me already you've got quite a lot of knowledge, and I've observed how you interact with patients. And I think I let those go through those patients, just go through the whole history and examination, and then question them afterwards about what they thought. Teacher_04

Some teachers highlighted that even if the student appears to have adequate knowledge, confirmation of this through discussion is always a useful exercise and aids learning.

> "I think sometimes if a student understands the concept, you're not always aware of how they got to that point I think." Teacher_04

> If students just jump to diagnosis – would still encourage discussion about the condition – unlikely to just encourage NAR alone. Faculty_02_reflection

Likewise, students were aware of the usefulness of discussing how and why they had reasoned through a clinical case regardless of their level of clinical domain knowledge.

> "GP tutor would say take a history and then try and sort of talk through what you think it's going to be. And my mind always goes from as soon

as I hear anything I think from the first symptom I try and do pattern recognition…I think if you know what the answer is you should know why the answer is right. Because feeling like you know what the answer is but you're not sure why, you still feel very precarious like that." Student_02_interview

Having to explain her reasoning – likes this, having someone check reasoning useful. All the time useful. If high knowledge, at this stage of medical training, still useful, but if very good knowledge (appendicitis), still useful in the long term to embed with practice of reasoning. Student_13_reflection

Sometimes not much information available, NAR can be encouraged in these cases. Might be encouraged to find out more information based on 1st impressions (both NAR and AR). Mostly are asked to explain reasoning after giving the right answer. Student_14_reflection

Virtual cases – encourage first impressions and then encouraged to use analytical thought. Structure helpful to novices and aids insecurity. Provides a scaffold to reason with. Student_10_reflection

Some students were mindful that that they wanted to be able to use NAR and focus down more once they had adequate knowledge as this would be expected of them in assessments. Without this, there is resultant frustration at teaching activities being misaligned with assessments requirements.

"So, there's a big tension, I think a lot of people feel this way, in teaching, the teaching that we have, which is explicit teaching by,

especially by consultants, versus the way that we are examined. In that quite often consultants want us to be really thorough, and teach a model or approach which is then, it's impossible to do in an exam situation…if you come to an exam, and you've only done a quarter of the station by the time it's over, that is quite a strong incentive to change the way that you're doing things." Student_01_interview

Students were also mindful that non-analytical reasoning could be wrong and so using both forms of reasoning felt safe, both for practice and in learning situations.

"I think I'm pretty sure I've never gone in, thought it was something, asked questions about that and then left without asking questions to rule other things in or rule it out. So, I think it's only encouraged obviously to use your gut in a way, but never trust it. Have it there as a good guide, but also be quite aware that it could be wrong." Student_05_interview

What could it be and then speaking through your reasoning – both T1 and T2 – best. Student_11_reflection

Therefore, encouragement of both forms of reasoning during teaching and learning encounters, provided the students have adequate knowledge was overall felt to be the safest and most effective way to learn and develop CR. Encouragement of both types of reasoning could occur in various educational activities and were theorised to result in mechanism responses of greater understanding and consolidation, refinement and clarification of knowledge which aided CR development.

Revised CMOC: Encouraging analytical and non-analytical reasoning; adequate clinical domain knowledge

Once adequate clinical domain specific knowledge is developed (C), interventions which encourage both non-analytical and analytical reasoning (Mresource) are felt to be effective and safe (Mresponse) for both teachers and students, aids understanding (Mresponse) and consolidation of knowledge (Mresponse) and has a positive impact of CR development (O).

Knowledge acquisition, retention, and recall

Whilst knowledge acquisition alone is insufficient for the development of CR, it is vital to acquire knowledge to develop illness scripts which can be applied when reasoning through clinical problems. Pre-existing knowledge is also a key context in this research when determining effectiveness of individual interventions for student. Therefore, activities and interventions which allow knowledge to be acquired, retained and recalled feature in the required resources for effective development of CR. These interventions indirectly promote development of CR through other educational activities that require clinical domain knowledge to enable engagement and positive educational outcomes.

Learning strategies that can be incorporated into multiple teaching and educational activities are proven to promote long term retention of knowledge. These strategies have been discussed in Chapters 2 and 5 as knowledge acquisition using these strategies was found to be beneficial to students regardless of their pre-existing knowledge level or if students were being taught in a group (see Figure 13). The following sections detail the development of 2 CMOCs in this phase of the research, where the mechanism resource was knowledge acquisition, retention and recall.

Teacher and student training and incorporation of learning strategies

The realist review found the following with respect to knowledge acquisition:

When there are different levels of knowledge within a group (C), a teaching approach designed around effective learning strategies to increase long term knowledge retention (Mresource) aids continued development and understanding about the process of clinical reasoning (Mresponse) which has a positive impact on learning outcomes, development of non-analytical reasoning and building or refinement of illness scripts (Outcome).

This CMOC was based around teachers integrating learning strategies into their teaching to improve long term knowledge retention. The findings were applicable to all stages of students' training and were helpful regardless of the pre-existing knowledge.

Throughout the realist evaluation it was noted that students need to understand how to best learn. This may come from training and teaching about the integration of learning strategies into their self-directed learning and revision practices. Faculty members felt that it was important that teachers knew how to teach effectively including in the incorporation of effective learning strategies.

"…teachers have to be given structure on how to teach." Faculty_02

Some students noted that they were explicitly taught or had self-taught about common learning strategies:

"I've also been taught about the Pomodoro technique, the 25 minutes on, 5 minutes off. I tried it and then gradually extended it to 45 minutes

on, 15 minutes off and then an hour on, ½ an hour off…I just couldn't do enough in that 25 minutes." Student_03_focusgroup

"I'll see a condition or get taught about it and then I'll read about it afterwards. Doing that is much better because when you start your revision when you've already seen the case, or having already been taught about it, you form the links a lot easier." Student_04_focusgroup

Learning about a case – tries to relate case to people – uses concrete examples even if they are made up. Has knowledge of how she best learns and demonstrates use of learning strategies, and this makes it more interesting to her. Has found her own information on learning strategies but not been taught. Student_11_reflection

However, most students voiced that they had never been taught how to learn most effectively and this is likely to have a detrimental effect on long term knowledge retention which will negatively impact on CR.

"No one teaches us how to revise, never in my whole 18 years at school does anyone teach you how to study they just teach you what you need to know and expect you to do something with it". Student_01_focusgroup

Little advice about revision, struggle with long term retention of knowledge and the right context, seems confused about what clinical reasoning is and how do you do it. Learning strategies not forthcoming from teaching fellows, not taught explicitly to all. No general advice

about strategies or how to learn from the medical school. Student_12_reflection

"I'm still obviously learning about different ways to learn, so I'm still figuring out what helps." Student_02_interview

Some students recognised certain educational activities were useful even if they did not realise that these activities incorporated certain learning strategies. These students demonstrated they understand concrete examples are useful.

"…just having the experience of a patient rather than an exam or textbook presentation, like having a real, having spoken to them you kind of remember that for the future." Student_03_interview

"I watch videos, I read the book, I write my notes and then I try and find a patient. That's the way that I do it." Student_02_interview

These students noted that retrieval of information and spacing were valuable strategies.

Repetition also helpful, repeated and perhaps with increasing complexity throughout medical school. Student_15_reflection

Saying it out loud and answer questions (retrieval) helps recall, practice, rolls off the tongue. Used to saying certain things, enables accessing

> other knowledge to help answer more complex problems. Student_13_reflection

Student participants also highlighted that not understanding how to best learn was unhelpful to their learning and knowledge acquisition. This student had failed her end of year examinations but had insight her ways of revising were not effective:

> Harder to make the connections between neck pain and diagnosis, different conditions 'very spread out in my brain', not making links between them. Self-directed learning, using disease based, insight that this isn't a good idea. Every year thinks things aren't working and need to find a different way. Used to write notes but wasn't working. Has found some information online. Student_08_reflection

Teachers and faculty in this research study were all in positions of being actively engaged regularly in medical student teaching and therefore most understood the strategies they could incorporate into teaching to make it more effective for long term knowledge retention. Some teachers actively shared this knowledge with students to aid their self-directed learning:

> Participant: "I like to do lots of drawings as well. So, I think it lends itself to thinking this sort of way. [I ask the students] 'Do you use flash cards, use mind maps or something?', because then knowing that I can potentially incorporate that way of learning. Most of them tend to just say standard things like just read books again and again, which I discourage them, and I try to give them resources that they can use."

Researcher: “What kind of resources?”

Participant: “So, The Learning Scientists one’s always... That’s a really good resource; that’s my go to.”

Researcher: “So you’d encourage them to do spacing and not just reread books, but actually use those learning strategies?”

Participant: “Yeah.” Teacher_02

Many clinical teachers in this research demonstrated that they incorporated learning strategies into their own teaching.

“…put up a worked example on screen, talk through that. Give them the opportunity to ask questions, which generally works. I might attempt to draw stuff on the whiteboard or whatever just to illustrate a particular thing.” Teacher_03

“So, they like quizzes, like we do a revision session every time at the beginning just to test their knowledge before prior to the session last week and they like that. We revisit last session, previous session in CP1, just to get them like reinforce their knowledge.” Teacher_06

Throughout this research, it has been theorised that when students have higher knowledge, they feel more confident to engage in various educational interventions that aid CR development. This was demonstrated by

this faculty participant when referring to preparation and knowledge acquisition prior to commencing clinical placements.

> "I think the ones who've already done some of the activities before coming in, it helps to consolidate what they've got and then also clear their doubts. So, their knowledge basis is larger than the ones who haven't done the activity. And then it gives them an opportunity to interact with more confidence." Faculty_01

The mechanism responses of understanding, feeling more confident and engagement in various educational interventions were all felt to be responsible for why teaching or self-directed learning that incorporates learning strategies, ultimately aid CR development. Knowledge acquisition alone is not enough to promote CR development, but long-term knowledge retention and recall is needed to promote engagement in other activities that do develop CR.

Revised CMOC: Knowledge acquisition, retention, and recall; Teacher and student training and incorporation of learning strategies

When teachers and students learn about, and incorporate into teaching or self-directed learning, learning strategies (C) that aid long term knowledge acquisition, retention and recall (Mresource), understanding and long-term knowledge retention is improved (Mresponse), students feel more confident in their knowledge (Mresponse) which increases engagement (Mresponse) in all educational activities and interventions that develop CR (O).

Promotion of teaching by patient presentation and access to a variety of patients

Understanding that students having access to a variety of patients and teaching that led from patient presentation rather than pre-diagnosed disease emerged and developed throughout the research. Teaching that promotes learning from these 'undifferentiated' patients is supported by illness script theory (Custers, 2015b, Lubarsky et al., 2015) and cognitive flexibility theory (Spiro et al., 1988). Clinical teachers tried to ensure that students had access to cases where the diagnosis was unknown, or the patients' symptoms were yet unexplained.

> "…rather than having a case where he definitely knew what it was, say appendicitis, it was just acute abdomen, and he would discuss various different things that would make you think one way or another; the different things with similar presentations…it was coming back out from the original presentation to sort of check our pre-clinical knowledge." Student_05_interview

> "…conditions will be based around the clinical case scenarios. We throw the scenario first, and we work together about what could be the condition, how we treat the patient, what's the best management, the first line management adopted." Teacher_05

> "…how would they present as skin infections; how would they present and how would it be different from an inflammatory condition. Skin cancer: how would that present as and how would that be different from a benign lesion, for example. So, the history will guide your

examination findings. And then basically when you examine the patient, you will either confirm or refute your findings." Faculty_01

"If the student goes off and clerks somebody who's having irregular periods you will be able to talk about the endocrine control of the menstrual cycle, so basic physiology. You'll then be able to hang that on to pathology. You know, polycystic ovarian syndrome. Is it a hypothalamic cause? Is it premature ovarian failure?" Faculty_02

It was noted that having access to a wide variety of patients and their presentations was vital. This enables comparing between patients with different presentations and the same diagnosis or the same presentation and different diagnosis.

"We kind of would play three or four videos in a session like that where the diagnosis is the same but everybody's story's different also. So that they can appreciate that everybody's going to tell you a different story but they're all going to have key elements and tell you this is cardiovascular chest pain, so the site, the radiation, the duration, the nature of the pain and that sort of thing; so, appreciating patterns but also unique individual differences as well." Faculty_03

Within this framework of teaching by patient presentation and ensuring access to a wider variety of patient presentations, there was a recognition that the approach would need to be altered depending on the students' knowledge and experience.

> "…example of angina or myocardial infarction, they'll say kind of all the expected things, whereas, a patient, a real patient might describe it differently. So, they'll do a session like that fairly close to the beginning of a module. They might do some case-based discussion on a vignette and try and just brainstorm how a patient might describe the symptom of chest pain and then towards the end of the module they'll see some real patients who have had those conditions and then they'll hear about the variety of the ways in which patients will describe it." Faculty_03

The curricula structure at Nottingham University was changing to incorporate teaching by presentation as a way of developing CR.

> "…to recognise and to understand how things present and then to build onto, obviously to understand the different presentations and the potential variants, variations in that presentation. And then the working out whether that fits or doesn't fit and if it doesn't fit… we're moving away from just a learning outcomes-based model, or a, into case presentations, and we are, and there's a clinical method model with clinical reasoning process incorporated in it." Faculty_04

Faculty members corroborated that the change in the curriculum would hopefully enable a symptom-based approach to teaching as described here:

> "I'm wondering if the new curriculum will allow that with the sort of, you know, symptom-based approach, making them think much more not in, you know, this is asthma and this is how you present with asthma. But actually, if somebody had a cough, what other things could it be?" Faculty_05

Faculty and clinical teachers in this research understood the value of teaching by patient presentation and a wide variety of patients and similarly, students appreciated the importance of this to their CR development:

> "I've learnt, not learnt clusters of diseases but to learn by presenting complaint because that's more relevant to what you actually see. Because if you learn by disease, you have these individual islands of knowledge (yeah) and they don't connect, whereas if you say today, I'm going to learn about chest pain, and you learn the diseases like that then they all sort of link back to chest pain. So, when someone comes to you and says, 'I've got chest pain', then you've already got those links, you don't have individual islands of knowledge that you have to force together." Student_01_focusgroup

> Had lecture on headache, helped her assimilate common differentials and what questions to ask to differentiate. Felt more confident with this presentation. Felt significantly easier to approach an OSCE station that included headache because of this method of teaching about headache. Student_08_reflection

However, students also alluded to the fact that some teaching did not always teach using this approach.

> "It would be good if when people are lecturing or giving a teaching session on say a case or condition if they could put a couple of cases, like 1 slide with a brief rubric at the end of their PowerPoint, that could be a few things [diagnoses]." Student_04_focusgroup

> Asked to interpret an ECG to identify heart block, even though she had learnt about heart blocks, couldn't work from symptom to diagnosis – "I've learnt it but it's not working, it's not coming out in the clinical scenario." Mostly learned about heart block from textbooks and lectures, knowledge of heart blocks rather than being taught from presentation to disease. Student_08_reflection

> Knowledge is delivered 'backwards', delivered from diagnosis back to presentation. Patients present with symptoms. Student_09_reflection

One student noted that early in the medical course, teaching from diagnosis and a structured approach was utilised whereas in the clinical phases, teaching from patient presentation is more commonplace. They, and other students, felt this transition was quite abrupt and one that would be eased if the notion of teaching from patient presentation was introduced earlier in the medical course.

> "I think when we were taught history taking, you're taught it in this very general way, or you're taught it in a system specific way, which is actually, really unhelpful when you're presented with a real person, with a real patient. The same is true for examination, the system examination is of limited use. I feel we spend the most time on now actually is thinking of things in terms of presentations and the assessment of a presentation, rather than about specific pathologies. So, all my learning and notetaking, and in fact really teaching, has always been centred around pathologies or bits of anatomy or whatever, and whilst, going through clinical phases to become much more presentation based… I think just having that maybe more in the

teaching from earlier on would be easier to make that sort of transition. So, for instance it's all very well and good to know tons and tons about subarachnoid haemorrhage, but you need to know the other differentials from a headache presentation. And if you don't, you won't be able to assess a headache well no matter how much you have read about a specific subject that might cause it." Student_01_interview

Teaching from patient presentation has been reported to be an effective way of developing CR ability (Schmidt and Mamede, 2015) and is incorporated when teachers and university curricula are aware of the benefit and effectiveness of teaching in this way. Both a wide variety of patients and teaching from patient presentation enable better longer-term knowledge retention through incorporation of learning strategies such as interleaving which enables connections to be identified and comparison and contrasting between different patient and different presentations. This in turn aids knowledge retention and development of illness scripts which are needed for effective CR. As previously mentioned, knowledge promotes self-confidence and engagement in other activities which aid CR development.

Revised CMOC: Knowledge acquisition, retention, and recall; Promotion of teaching by patient presentation and access to a variety of patients

When teachers and university curricula promote teaching by patient presentation (C) or have access to a wide variety of patients (C) knowledge acquisition, retention and recall is improved (Mresource), promotes illness script development which improves student self-confidence (Mresponse) and promotes engagement (Mresponse) in all educational activities and interventions that develop CR (O).

Interpretation of refined CMOCs

The results highlight a range of independent and inter-dependent contexts that affect different resources offered by educational interventions together with the potential responses of students exposed to the various interventions that accounts for the predicted outcome and effect on CR development. The CMOCs describe either a positive effect on CR or where the impact may have a lesser effect on the development of CR or where there is a reduction in opportunity to develop CR. Whilst these CMOCs have been refined, realist approaches to research do not describe the results as final or complete, since context is always changing and there may be elements of educational interventions to develop CR that have not been considered by this work. The results of the realist evaluation are discussed alongside the existing literature and recommendations for practice in Chapter 8. Figure 16 visually represents the overall findings of the research, however it should be noted that realist research findings are unique in their ability to provide generative explanatory statements. In addition, Figure 16 shows all the components that make up the CMOCs as the main findings but not how they interact. The value of the visual representation is to aid the reader in understanding the research output but given that "any single visual representation is unlikely to sufficiently articulate the programme theory" (Skivington et al., 2021), the diagram must be used in conjunction with the narrative explanation of CMOC development from this chapter to fully appreciate the ways in which various educational interventions develop CR.

Strengths and limitations

Throughout the research process, how the data has been interpreted through a realist lens has been discussed. The realist research process is

iterative and interpretive. In this way, the researcher's experiences and knowledge impacted on the interpretation of the data. When viewed from the positivist standpoint, this may be seen as biased as the researcher is not deliberately separated from the data. However, in realist research, whilst the researcher should be mindful of their views and how this could be affecting interpretation of the evidence, the researcher's opinions and experience assist in the development of the theory throughout the realist research process.

In research where all the data is collected at once within a short timeframe this doesn't enable data analysis alongside its collection. In this study, two rounds of data collection were used over approximately 12 months with data analysis ongoing through the process. This enabled later interviews to focus on specific issues raised by earlier interviews and confirm or refine developing theory and is a specific strength of this research.

The study does have several limitations, however. The project being completed as part of a PhD limited the time and resources available to collect and analyse the data. The audio data were listened to whilst the researcher made reflective notes about the evidence which were linked with developing CMOCs. These data were used as part of the evidence for developing the CMOCs. As realist research is interpretive, and the reflective notes were consistent with the content of the interviews, this was a valid approach to data analysis. During the presentation of the results, whether the evidence is a first-hand verbatim quote with its associated interpretation considering the developing CMOC or a reflection made by the researcher is made clear to the reader. If more time had been available in the research or more resources been available, ideally the researcher would have re-explored developing CMOCs with participants which may have led to further refinement of the theories or additional data to evidence their validity.

Participants in this study were purposively sampled based upon their experience with developing CR as a teacher or faculty or through their experience of it as a student. All the participants were invited to participate but only those who agreed to participate were included. For the smaller group of clinical teachers and faculty members, this is less likely to have had a significant impact but for the student participants, there is a potential self-selection bias, with students who already have knowledge of the topic more likely to put themselves forward for selection. In the first round of interviews, this was seen to be the case, with most of the student participants being graduate entry students and some having a good understanding of the research, more than would be expected from the student population. The 2nd round of interviews with students was undertaken to further examine the student experience of CR development and in this group, a wider range of students agreed to participate including some students who has previously failed assessments which enabled a good comparison of those students who could be viewed as high performing with those who may have been struggling with their CR development.

Summary of chapter

This chapter has presented the main results of the realist evaluation and their development through the gathering and analysis of qualitative data, interpreted through a realist lens. Throughout the descriptions, the researcher has sought to make their interpretation of the data clear and where possible, demonstrate how the revised programme theories developed from the realist review or emerged de novo in this phase of the research. Data were collected from medical students, clinical teachers and faculty at the University of Nottingham. Five mechanism resources were identified although, as articulated, many different educational activities and interventions provided these resources, and some educational interventions provide more than one. Holding true to the realist nature of this research, the contexts that affected

those mechanisms and a further description of the potential mechanism responses were detailed to fully describe the effect on CR development. Educational interventions can provide resources that have a positive effect on CR development or in certain circumstances, situations or for certain groups of students, the effect is lesser or there are reduced opportunities for students to develop CR.

Chapter 8: Discussion

This chapter surmises the aims of the research and the main findings with a discussion of the findings relative to the existing literature. Recommendations for educational practice, curricula design and educational policy are discussed before considering recommendations for research. The limitations of the research and impact of COVID-19 are also considered.

Aim of research

CR is a ubiquitous requirement for medical students and doctors. Its development takes many years through various educational experiences and interventions, from undergraduate through to continuing medical education after post-graduate training. It is continually evolving through experience and learning. Undergraduate medical education lays the foundations, therefore, for a lifelong process of CR development. Education and learning are complex interventions, with many interacting contexts that affect the multiple outcomes. Education to develop CR is no different to this and research must consider the factors and contexts that affect the potential outcomes to fully understand whether various educational interventions will likely work or not in certain circumstances. This research set out to answer the question, in what ways do educational interventions develop analytical and non-analytical clinical reasoning ability among undergraduate medical students? What works for whom, in what circumstances and why? The findings allow us to understand which interventions may develop CR but more so, allow understanding of how those interventions produce their effects and why those outcomes may differ for different groups of people or in different circumstances.

Summary of the research process

This research has utilised a realist review and subsequently a realist evaluation as detailed in Figure 18.

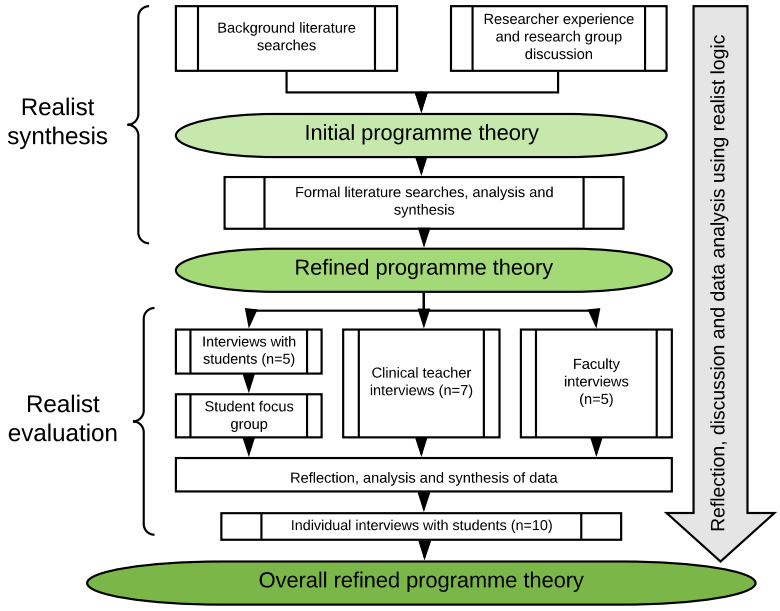

Figure 18: Overall research approach leading to overall refined programme theory

The research commenced with background searches, research group discussion and, combined with researcher and research group experience, initial programme theories (IPTs) about how CR is developed through education were created. These IPTs were refined through formal literature searches, analysis and synthesis using realist logic. The first phase of the research, the realist review, produced refined programme theories that were tested using realist qualitative individual and group interviews with students and individual interviews with clinical teachers and faculty at the University of Nottingham Medical School. These qualitative data were analysed and synthesised, again

using a realist logic, to produce a refined theory of that ways in which educational interventions develop CR in medical students.

Summary of the findings

Educational interventions to develop CR in medical students are varied, some specifically designed to develop CR, and some develop CR even though this may not have been the intended outcome. Overall, undergraduate medical education develops satisfactory CR for most students through acquisition of knowledge and practice and participation in CR tasks. These activities enable development of illness scripts which develop further through a clinician's working lifetime. In general terms, the more experiences with feedback that are received, the more developed and fuller the illness scripts are. This enables more accurate non-analytical reasoning at the point of patient contact and an appreciation of when 'something doesn't fit' (Croskerry, 2018). This is the definition of expert clinical practice and CR.

Specifically, to develop CR students must acquire and retain knowledge specific to different clinical domains, participate in CR tasks with or without encouragement to use specific reasoning processes, learn from mistakes and learn about the CR process generally and specifically to clinical cases. These resources are offered by various interventions and often, one educational intervention provides more than one resource. In addition, the contexts that impact the educational effectiveness of these interventions are both independent and inter-dependent of each other. Often more than one factor or context impacts at one time, these contexts change for students over the course of their studies and are often specific to one moment in time or a clinical case rather than the same contexts affecting outcome universally. This makes educational interventions to develop CR, understandably, complex but the

findings do allow us to illuminate where different interventions, changes to interventions or changes to context may be needed to make education more effective at developing CR. This is important to attain the goal of making future clinicians the most effective at diagnosing and managing patients' problems.

An important factor in determining whether an educational intervention is effective at developing CR is the pre-existing knowledge of the student relative to the clinical case. This context changes rapidly for students, over the course of their undergraduate training but sometimes over the course of one clinical encounter. When knowledge is sufficiently high relative to the clinical case, most educational interventions to develop CR will be effective although, in these circumstances, educators need to be aware that employing educational techniques that would be helpful for novices may not achieve the same effect (Kalyuga et al., 2003). In these cases, enabling and encouraging students to trust their instincts and not just enforcing analytical reasoning is required (Richmond et al., 2020). When knowledge is low relative to a clinical case, understanding, and the resultant learning and development of CR, occurs when a more detailed explanation of the case is given. To enable this, a motivated teacher with sufficient time to give the explanation in a way that the student can understand is required or support and encourage analytical reasoning. When clinicians are expert in a clinical domain, they may not be able to explain their reasoning in a way that students can understand due to the subconscious nature of type 1 reasoning (Evans and Stanovich, 2013). In these circumstances peers or near peers can provide this explanation without as much cognitive effort as their reasoning processes may be tending more towards type 2 processes which are amenable to conscious introspection. Despite this, motivation of the teacher is a more pervasive context when determining effective CR development through explanation of a clinician's CR process. A teacher's motivation to teach and confidence in their student, as well as their own ability, is also necessary to enable active participation in CR tasks.

Having a rapport and relationship established between the teacher and student was found to be important to enable students to ask questions to deepen their understanding of the CR process. Whilst students occasionally felt more able to ask questions to educators of a similar age or stage of training, they felt able to ask questions of expert clinicians who took time to build a relationship with their students. The context of a positive student-teacher relationship or rapport also enables students to learn more effectively when mistakes in learning occur and enables teachers to identify those students who have sufficient knowledge in a clinical domain and appropriately allow these students to use NAR during CR.

A student's self-confidence in their own ability or confidence in their knowledge determined whether students were able to engage in CR tasks. Those students with adequately high self-confidence were able to actively participate in CR tasks, learn from mistakes and feel at ease when asking questions to improve their understanding. When a student's self-confidence is low, this may impede engagement with CR tasks, reduce acceptability of making and, therefore, learning from mistakes, and more support is required from motivated teachers to assist students through CR tasks. Additionally, adequately high self-confidence combined with clinical experience was felt to be needed for students to be exposed to more complex and uncertain aspects of CR which are commonplace in clinical practice. Increasing exposure and experience with uncertain and complex cases, is likely to enable effective illness script development and therefore overall CR.

A student who has experience in the clinical environment also had greater confidence and subsequently was more likely to engage with educational opportunities including participating in CR tasks. This was also true of students with a mastery goal orientation who view medical school as a

means to develop effectively as doctors. If students have a growth mindset or mastery goal orientation, this enables them to value mistakes as learning opportunities, further engage in tasks where mistakes were possible, and increase exposure and experience to a wide variety of patients, all vital for illness script and CR development.

From a wider educational and organisational perspective, actual and perceived available time to teach and available space and resources impacted greatly on opportunities for students to participate in CR tasks. Active participation in CR tasks is a mandatory component of CR development and lessening opportunities is likely to have a great impact on students' overall clinical experience and, although not a focus of this research, satisfaction. It was noted that assessments also impact significantly on educational interventions to develop CR where students are less likely to attend and therefore engage with the clinical environment, particularly for complex of uncertain cases, when examinations are imminent. For some students, the perception that medical school assessments are purely knowledge based may lead them to disengage with the clinical environment entirely, believing that exams can be passed with the knowledge they acquire from non-clinical experiences and textbooks.

Finally, medical school curricula need to acknowledge the importance of CR in order that educational interventions are supported which are more likely to develop CR. This includes students learning specifically about the cognitive aspects of the CR process to promote more effective reflection on clinical cases and promotion of educationally effective instructional techniques. These include, but are not limited to, ensuring teachers and students are trained in the use of learning strategies to enhance knowledge acquisition and promoting teaching from patient presentation or symptoms.

Overall, a combination of educational interventions and instructional approaches are required to effectively develop CR in medical students, each of which is impacted by at least one context related to the individual student, the teacher or the wider educational or organisational environment. These findings have implications for educational practice, curricula design and policy and for research which will be discussed in the subsequent sections.

Implications for educational practice

Individualising education

It has long been accepted that CR is very idiosyncratic given that acquisition of knowledge through experience is unique to the individual student or doctor (Gruppen and Frohna, 2002). The individuality of education is thought to underpin differences in CR behaviours. This research demonstrated that multiple contexts pertaining to individual differences impacted various educational interventions to develop CR and it is felt likely these factors will impact all of learning within medical education. This highlights the importance of individualising education to optimize outcomes (Schwinn et al., 2019), including in the development of CR. Successful individualisation of education has been demonstrated in other areas, including in the development of teaching competence in General Practitioners (Schol et al., 2005) and when incorporated into a competency based educational programme (Gruppen et al., 2016). Individualisation or learner centeredness is core to competency based curricula (Frank et al., 2010) and similar principles could be applied to CR development as a core competency of medical education (Gruppen, 2017). In addition, it is suggested that a sign of a good clinical teacher is their ability to individualise teaching to the student's needs (Harden and Laidlaw, 2012).

Individualisation could occur within multiple educational interventions to improve CR development but firstly requires a detailed understanding of the student's clinical domain knowledge, potentially being assessed on a case-by-case basis. This understanding is needed to determine the level of discussion, explanation or specific feedback required to aid understanding, whether a student can be appropriately allowed to use NAR and to enable direction towards cases of higher complexity and uncertainty once clinical domain knowledge is deemed to be adequate. Secondly, a student's self-confidence or self-efficacy beliefs also impact how they approach and interact with a CR tasks (Zimmerman, 1990) or educational interventions, particularly when the task involves working in real clinical environments or interacting with patients. The findings of this research predict those students with lower self-confidence, self-efficacy beliefs and lesser experience in the clinical environment will require motivated teachers to support and scaffold CR to sustain its development. Identification of these students' factors is therefore important in appropriately targeting educational interventions. Currently, undergraduate medical education often remains unadjusted for personal and individual characteristics and abilities and frequently provides a 'one size fits all approach' (Schwinn et al., 2019). For most students who are high achieving, highly intelligent individuals (Sayer et al., 2002), this approach is adequate but there will be some students who fail to thrive and require an adapted approach (Johnson and Leech, 2022, Kirtchuk et al., 2022).

The approach to accomplishing individualisation of educational interventions to develop CR, considering students' clinical domain knowledge and self-confidence, in the current educational system, depends significantly on the teacher (Ribeiro and Moura, 2020). Firstly, teachers need to assess the individual's knowledge relevant to the clinical domain and, this research demonstrates that the teacher's perception of the student knowledge state

may be judged initially on the outward confidence of the student. Whilst the relationship between knowledge, self-confidence and engagement in educational tasks has been noted in this research, the students' outward confidence is not always correlated with clinical domain knowledge of the task. Indeed, novice students can demonstrate inappropriately high levels of confidence, so called an 'unconsciously incompetent' student as demonstrated by the Dunning-Kruger effect (Dunning, 2011). The task for the clinical teacher is not straight forward and requires a great deal of skill to both assess knowledge and then amend educational interventions accordingly. This is not insurmountable however, and where teachers are motivated to understand a student's knowledge through discussion of cases (Ribeiro and Moura, 2020) and where continuity of a student-teacher relationship exists, individualised approaches to education can be then incorporated.

Knowledge within a clinical domain progresses over time and assessment of knowledge and the subsequent adaptations to educational interventions needs to be regularly reassessed and amended according to the learning curve of each student (Pusic MV et al., 2015). Secondly, teachers need to assess the students' self-confidence when approaching CR tasks in the clinical environment to gauge the level of support they require. Insufficient support for these students will lead to lack of engagement in the clinical setting and subsequent loss of opportunity for CR development. Additionally, support, encouragement and provision of psychological security is required for students who lack self-confidence or who perceive making mistakes are unacceptable, highlighting another modification in teaching style required for this group of students. Assessment of knowledge and self-confidence 'in the moment' is not an easy task for educators, especially against the backdrop of clinical education alongside competing roles such as providing patient care and service pressures within the health service. This therefore warrants consideration of how medical educators and organisations might incorporate approaches that enable individualisation of student education.

As noted, medical educators, especially those motivated and able to spend time building relationships and understanding of their students' requirements, can adjust instructional techniques according to the students' knowledge and self-confidence, amending these as the student contexts change over time. This is done through discussion of cases (Ribeiro and Moura, 2020), formative assessment and feedback. Current circumstances often do not enable this continuity of education however and students may be faced with educational activities where they have never met their clinical educator previously. Where both student and educator are motivated and confidence is sufficiently high in both parties, the learning experience is likely to be valuable. The risk is that teachers can be distracted by their patient or service commitment or unwilling to support education and students remain only passive observers (Spencer, 2003, Dornan et al., 2007) which fails to meet requirements for the active participation in CR tasks required for development or any individualization of the learning encounter. Given the pressure on healthcare resulting often in a perceived lack of time and resources to prioritize education over healthcare (Buja, 2019), innovative ideas to develop CR in the current climate need to be given attention. Adaptive e-learning environments (AEEs) (Fontaine et al., 2019) provide a potential avenue for exploration to attend to these issues. E-learning environments have been incorporated into many educational programmes for some time but mostly included non-adaptive structures, that is they provide a structured, non-individualised approach to education (Fontaine et al., 2019). Adaptive e-learning considers the learners' knowledge, skills and other relevant individual characteristics (Ruiz et al., 2006) to personalise the content. Adaptation to the e-learning content can occur at the beginning or has potential to be adapted through the e-learning package dependent on the students' responses to questions and cases (Fontaine et al., 2019). This approach could enable student specific feedback and appropriate allowance of mode of reasoning (NAR or AR) or level of explanation dependent on determination of the students' levels of knowledge. Not only does this approach enable individualisation on a case-by-case basis but the system could 'learn' with the student, providing learning

suited to their level of expertise. This is an exciting approach to CR development but is not yet incorporated into undergraduate curricula routinely and evidence to validate the potential benefit is low (Fontaine et al., 2019).

Most, if not all, medical degrees in the UK incorporate early patient contact as a positive aspect of their undergraduate medical programmes and this has been seen as advantageous in terms of enabling students to contextualise their basic science learning (Wenrich et al., 2013). At the time of writing, no undergraduate programmes have advocated for approaches that entirely forego learning in the clinical setting (Spencer and McKimm, 2010) but learning with patients is known to be unpredictable and comprises a degree of uncertainty (Spencer, 2004). Although contentious, teaching approaches that do not include learning with real patients in clinical settings would enable structured and individualised learning when AEEs are incorporated. Disadvantages of lack of patient contact including reduction in development of professional behaviours and communications skills which are prohibitive barriers to this recommendation. Given the emphasis and importance of individualised learning and the benefits of early and continued patient contact, a blended approach to learning in an adaptive e-learning environment, complemented by the traditional face to face learning with patients is proposed by this research to be the best of both approaches and supported by the literature which suggests "decoupling clinical education from clinical care" (Norman, 2012) would be advantageous.

When medical teachers are motivated, many educational techniques have been described to improve CR development and naturally require individualisation to be successful. These include SNAPPS[1] (Wolpaw et al., 2009)

[1] SNAPPS - **S**ummarize history and findings; **N**arrow differentials; **A**nalyze differentials; **P**robe preceptor about uncertainties; **P**lan management; **S**elect case-related issues for self-study WOLPAW, T., PAPP, K. K. & BORDAGE, G. 2009. Using SNAPPS to facilitate the expression of clinical reasoning and uncertainties: a randomized comparison group trial. *Academic Medicine,* 84**,** 517-524.

and One minute preceptor (OMP)[2] (Furney et al., 2001), both of which have shown efficacy in developing CR skills (Pierce et al., 2020). Some authors have suggested ways that medical teachers might become aware of CR difficulties (Audetat et al., 2013) and provide approaches that might be employed to remedy the issues. In each suggestion of why learners have CR difficulties, Audetat et al (2013) suggest clues available from direct observation or indirect observation through case discussion, both methods implying one to one interaction between student and teacher but the same authors highlight the challenges that can occur in implementing this including the culture focusing on clinical rather than educational goals (Audetat et al., 2012).

Self-confidence relative to a task is self-efficacy (Artino, 2012) and is part of a student's ability to feel able and prepared to execute a task. Self-confidence in the clinical environment or in their own knowledge base, affects students' ability to engage in CR tasks and the clinical setting generally. Students' self-efficacy beliefs impact their ability to actively participate in CR tasks and therefore the assessment of, and adaptation of, education based on these characteristics is likely to be valuable to students CR development. However, assessment of individual students' self-confidence, particularly their self-efficacy beliefs relative to a clinical cases, has been proposed to be challenging (Ribeiro and Moura, 2020). Self-regulated learning (SRL) theory (Zimmerman, 1990) includes self-efficacy as part of a number of individual variables including goal setting and strategic planning and other motivational beliefs that influence learning and outcome (Artino et al., 2014, Panadero,

[2] OMP – 1.Get a commitment—i.e., ask the learner to articulate his/her own diagnosis or plan; 2.Probe for supporting evidence—evaluate the learner's knowledge or reasoning; 3.Teach general rules—teach the learner common "take-home points" that can be used in future cases, aimed preferably at an area of weakness for the learner; 4.Reinforce what was done well—provide positive feedback; and 5.Correct errors—provide constructive feedback with recommendations for improvement FURNEY, S. L., ORSINI, A. N., ORSETTI, K. E., STERN, D. T., GRUPPEN, L. D. & IRBY, D. M. 2001. Teaching the One-Minute precpetor. A randomized controlled trial. *J Gen Intern Med,* 16**,** 620-624.

2017) as shown in Figure 19. Self-efficacy is part of the forethought phase of a task and when this is more effective, has been shown to be associated with better outcome in CR tasks (Artino et al., 2014).

Figure 19: Self-regulated learning as a 3-phase model. Adapted from (Artino et al., 2014) after (Zimmerman, 1990)

SRL theory can be utilised as part of SRL-microanalytic Assessment and Training (SRL-MAT) (Durning et al., 2011, Cleary et al., 2016) in order to identify how individual students approach, and think during and after, tasks and has also been advocated in the assessment of CR in students (Artino et al., 2014, Patel et al., 2015). To individualise CR development through education, SRL-MAT may have a role in identifying and correcting problems with CR but does require experienced teachers (Patel et al., 2015), faculty development and sufficient time to employ the technique appropriately.

Calls to individualise medical education have been made for some time but it is not without difficulty or cost (Klamen and Williams, 2011). As Gruppen et al state "Individualisation works but it is not cheap" (Gruppen et al., 2016) perhaps fundamentally underpinning the reason for not universally adopting this approach across medical education already. Some other challenges predicted when providing an individualised approach include the significant difficulties in creating personalised learning plans, assessments and collaboration between faculty and with students (Gruppen et al., 2016) and has been described as "labour intensive" (Sayer et al., 2002, Klamen and Williams, 2011). Compounding this problem is pressure to train and provide more doctors to tackle NHS workforce issues (MSC, 2021) potentially leading to inability to provide sufficient staff to adapt their approach to each student. Collectively, these concerns mean true individualisation is highly challenging in the current educational system and culture (Audetat et al., 2012). Individualisation within remediation programmes (Klamen and Williams, 2011) or for struggling students (Durning et al., 2011, Kirtchuk et al., 2022) have been advocated and may well be more sustainable due to the smaller numbers of students within these targeted programmes. These approaches fail to elevate all students to their highest potential however, and do not have capacity to allow all to strive for excellence. Further thoughts of how to adapt educational interventions or curricula when individualisation is not possible are considered in some of the next sections.

Developing students as learners

This research has highlighted that in CR development, student characteristics and pre-existing knowledge and traits either promote or hinder CR development in different educational situations. It is known that when students have a good knowledge base, their learning is more efficient. This is demonstrated by the Matthew effect described in literacy attainment (Walberg

and Tsai, 1983) where gains in learning occur faster for those with better literacy skills which results in an attainment gap as time goes on. This finding can also be explained by Cognitive Load Theory (CLT) (Young et al., 2014) whereby increasing knowledge is likely to reduce intrinsic cognitive load (the load by the task itself) and therefore increase capacity for germane load and learning. In medical education, this research proposes that knowledge is a key factor in determining how students can interact and therefore learn, from a wide range of educational interventions and activities. The research therefore supports the notion that development of basic biomedical knowledge followed by integration into clinical practice (Woods, 2007) promotes the development of CR. Given that knowledge is so vital, the role of integration of strategies to aid knowledge acquisition, retention and recall also feature in this research. However, many participants revealed they were not always aware of the best ways to learn as self-directed learners (Richmond et al., 2019). Given this is the case, attention needs to be paid to not just what students are taught but how they acquire the knowledge, both in formalised education activities and in how they self-direct their learning.

Evidence from the learning sciences has shown that knowledge is acquired and retained more effectively when certain strategies are applied to learning (Brown et al., 2014, Weinstein et al., 2018, Richmond et al., 2019). These approaches have been widely established in educational research and practice generally but also in the field specific to medical education (Hatala et al., 2003, Raman et al., 2010) and shown positive effects. Whilst the strategies have been widely promoted in the literature to educators (Norman, 2012), these strategies have not found their way into general educational practice (Weinstein et al., 2018) highlighting the important role of faculty development and teacher training. More relevant is whether these strategies have been endorsed to students as ways of supporting their learning. An output of this research was an article directed at students to guide them in application of the strategies (Richmond et al., 2019) but it is felt without integration of teaching

learners how to learn throughout their educational journey only a select few will access this information and even fewer will apply the evidence based approaches to their own study. Additionally, medical educators may view students as unmotivated to learn (Teunissen and Bok, 2013), particularly in the clinical setting but more attention needs to be paid to the reasons for this. One reason could be that medical students do not know how to learn in both self-directed and clinical settings.

By the time students arrive at medical school, they have already experienced many years of education but in that time, most will not have been taught how to learn (McGuire and McGuire, 2015), rather they are just taught, effectively or not. McGuire and McGuire's book highlights a key message that this research also strongly advocates for:

"If you teach students how to learn, and give them simple, straightforward strategies to use, they can significantly increase their learning and performance. The good news is that you will not have to change your entire course or devote an inordinate amount of time to teaching these strategies."
(McGuire and McGuire, 2015)

This quote illuminates a key message relating back to the previous section, if students are to do well in the current educational system, even where individualisation of education is not possible all the time, if they know how to learn, they will do better. There is a mass of literature pertaining to teaching doctors how to teach and teaching students how to teach (Dandavino et al., 2007), but despite several recommendations that self-directed learning (Murad et al., 2010) and independent study (Harden and Laidlaw, 2012) is important for students, very little literature published to date details the value of teaching medical students how to learn for themselves.

Whilst integration of the learning strategies, as shown in Table 4 in Chapter 2, have been shown to be effective for long term knowledge acquisition, learning in the clinical environment, required for CR development, provides additional challenges. In teaching students how to learn, McGuire and McGuire (2015) also advocate for the development of mindset and motivation in students to promote more effective learning. This research demonstrates that students who have previous clinical experience and therefore more confidence in the clinical setting or those who have a goal orientation towards mastery are more likely to engage in these settings and therefore have more opportunity to gain from experiences. A later section will consider the role of, and improving, clinical experience, whilst here, theories of motivation are considered (Cook and Artino, 2016) including how goal orientation (Chen et al., 2016) and mindset (Dweck, 2012) affect learning and how these might be developed in students.

Theories of motivation are numerous, terminology can be confusing and there is significant overlap between different motivational theories (Cook and Artino, 2016). This research specifically noted that students who demonstrated a tendency towards mastery goal orientation, that is learning with the intention of developing as a doctor, tended towards more positive learning in CR. This finding is supported by the literature of motivation, where mastery goal orientation promotes deeper learning (Teunissen and Bok, 2013) and performance orientation may promote a superficial learning style (Chen et al., 2016, Cook and Artino, 2016). The theory of goal orientation is closely linked to self-determination theory (SDT), which notes that drivers of motivation can be intrinsic or extrinsic, where intrinsic drivers of motivation leads behaviour based upon one's desire to satisfy a curiosity or interest or attain mastery (Cook and Artino, 2016). The literature is clear that motivation drives proactive learning and engagement (Ryan and Deci, 2000) and engagement improves

educational outcomes (Xu et al., 2022) but in order to enhance the mechanism of engagement in CR tasks or in the clinical setting, teachers need to consider how they might modify the motivational drivers of their learners.

Most medical students are motivated to learn in order that they can achieve the goal of coming to medical school, which is for the most part, to qualify as a doctor. However, as Custers and Boshuizen (2002) explain, students often state they want to learn for understanding, a mastery goal orientation, but their behaviour highlights a tendency towards cramming once the exams draw closer. Likewise, universities and teachers may state they wish their students to learn for medical practice, but the assessment processes may highlight a "fixed body of knowledge" (Custers and Boshuizen, 2002) to be memorized which promotes a tendency towards performance orientation. These are contradictory assertions and make research and understanding in this area challenging, rendered more so by a societal requirement to demonstrate that an 'appropriate level' of attainment and mastery have to be obtained prior to being able to practice medicine (GMC, 2018, Harden and Laidlaw, 2012). Notwithstanding the significant impact of assessment, which will be attended to in a later section, how can teachers influence students' motivational beliefs?

Cook et al (2016) summarise potential actions by teachers to improve motivation. Specifically with respect to goal orientation, recommendations to "instil an incremental (growth) mindset by reinforcing the human brain's limitless learning potential, reframing mistakes as opportunities for learning, and recognising effort as an important learning outcome in its own right" (Cook and Artino, 2016). These approaches to encouragement of effort in learning are reinforced by the principle of mindset (Dweck, 2012) and the element of learning from mistakes being normalised in medical education, which was highlighted by this research. When one views student potential as related to

their innate intelligence, it becomes fixed and unchangeable, but when potential is viewed as malleable, flexible and limitless, ability to change ones potential is possible (Syed, 2010, Dweck, 2012). Whether regular reinforcement and medical students' awareness and knowledge of mindset and goal orientation theories is sufficient to change their views however is unknown.

In the meantime, teachers should promote learning from mistakes by discussing their own mistakes and normalizing and viewing mistakes as opportunities in education (AU, 2020) and development of CR. They should promote the idea of desirable difficulties, that is effective learning feels harder but is more effective in the longer term (Brown et al., 2014). Setting achievable and incremental goals which provide challenge is also important and students can be encouraged to do this for themselves (AU, 2020). Teachers should not praise intelligence as this may reinforce the idea that this is a fixed trait, but rather effort and engagement even in the face of failure should be encouraged. Lastly, teachers need not only an awareness of the importance of mindset and encourage this in students, but they too need a growth mindset themselves to enable students to fully embrace the principles of a growth mindset to promote learning (Yeager et al., 2022).

Given the deep rooted nature of motivational beliefs that develop through childhood, upbringing and through school experiences (Dweck, 2012), change at multiple levels is required to change the ways in which students learn to learn. Indeed, Dweck's sentinel research into mindset is in school age children. Potentially by the late stage of higher education and in medical students, mindsets may be more strongly held and less amenable to change although some evidence exists to support interventions to develop a growth mindset in higher education (Cheng et al., 2021). More attention is being paid to encouraging growth mindsets from primary age children (Savvides, 2020) and this positive step will hopefully impact the medical students of the future

but more development is needed to create a culture of growth mindset (Dweck et al., 2020) throughout different stages of education. Evidence for development of students in order to make CR development more effective is challenging to deliver but the theoretical basis for this claim is well substantiated and there are recommendations to medical students to adopt a growth mindset (Scarola, 2020) to promote effective learning in medical school.

Optimizing and prioritising the delivery of education within healthcare

Despite the call to consider dissociating education from clinical care and the associated priorities over 10 years ago (Norman, 2012), clinical education still is mostly delivered alongside the patient agenda of the healthcare system in the UK. Clinical education is often not adapted for context at all. Instead, education is modified to suit the healthcare system rather than the system being improved to suit education. Norman (2012) notes that whilst we should continue to try and adapt clinical environments to optimize teaching, he also states "There is no way for educators to have any impact on clinical environments". The delivery of education whilst competing with patient priorities (Dolmans et al., 2002), inevitably results in a culture of educational objectives being deprioritized in order to meet patient need (Wearne et al., 2012). Education is important and has an impact in the longer-term on patient care (Graber et al., 2018) but the lack of short-term consequences when an individual's educational objectives are not met, coupled with competing demands of patient care means clinical teachers may not prioritize teaching (Schiekirka et al., 2012, Wearne et al., 2012). As making the most of each opportunity is vital to developing CR (Gruppen and Frohna, 2002), the culture surrounding the importance of education must improve in order to prioritise learning in the clinical setting.

This research has demonstrated that situating students in clinical environments to observe passively (Dornan et al., 2007) may not be valuable to learning for many students; the exceptions being those who already have a good knowledge of the clinical domain. Yet, the research also highlighted how students observe in clinical environments frequently and therefore understanding this intervention, and others that involve learning the in the clinical environment, that is learning with real patients (Harden and Laidlaw, 2012), is required. This research has demonstrated the important contexts that impact learning in the clinical setting. The factors pertaining to the student have already been discussed, so here the contexts related to the teacher and wider education or organisation will be considered.

It is well known that a clinical teacher has an important role in determining educational effectiveness (Harden and Laidlaw, 2012) and the teacher or supervisor has been found to be an important contributor to effectiveness of clinical rotations (Dolmans et al., 2002), more so than the patient mix or numbers of students to be taught. Doctors who excel in patient care have previously been assumed to be good teachers by virtue of their superior clinical knowledge and skill (Harden and Laidlaw, 2012), but this view is no longer so pervasive. Medical teachers need a wide range of skills to provide education that is based on the most effective evidence based educational practice, ability to adapt teaching for different groups of students, as well as an in depth understanding of their clinical domain (Woolliscroft, 2002). When teaching in the clinical setting, whether this be through observation, encouraging active participation or through discussion and feedback, this research identified that the key driver of teachers being able to adequately support students was their motivation to teach. This context superseded the impact of the level of expertise of the teacher and motivation is theorised to drive may of the features of a good clinical teacher including planning teaching effectively, appearing enthusiastic, serving as a good role model, encouraging and providing opportunity, providing feedback and

tailoring the teaching to the students' needs and stages of training (Harden and Laidlaw, 2012).

Despite this assertion, little work has been conducted on why some doctors are motivated to teach and others are not, with far more literature pertaining to motivation to learn in students (Cook and Artino, 2016), although similar self-motivational theories such as the impact of intrinsic and extrinsic drivers of behaviour are likely to be implicated (Dahlstrom et al., 2005). Clinical teachers who are motivated do so often for altruistic reasons, a desire to help students improve, through enjoyment of teaching or to showcase their specialty (Dahlstrom et al., 2005). Not only are motivated teachers likely to provide more effective clinical teaching, but motivated teachers may also be more approachable, helpful and available to students (Harden and Laidlaw, 2012), which aids in the building of rapport and a relationship which enables a deeper understanding of the students' needs. Discussion of individualisation of teaching based on students' needs has been undertaken in a previous section but the correlation between teacher motivation and student-teacher relationship is highlighted here (Tiberius et al., 2002). When a positive student-teacher relationship has been developed, students are trusted to engage in CR tasks, students also feel more able to learn from their mistakes in learning and to ask questions to deepen their understanding; all of which are important educational resources in the development of CR.

However, students in this research were often aware of teachers with low motivation to teach and the impact of this on CR development was considered and corroborated by the study by Schiekirka (2012). They highlighted that effective teaching is often completely reliant on the teacher and teachers may feel forced to teach by virtue of their job roles in teaching hospitals even if they are not interested (Schiekirka et al., 2012) which inevitably results in 'bad teaching'. It is likely to be the minority of teachers who

are not motivated to teach students at all (Dahlstrom et al., 2005) but there is also a fine balance of teachers' motivation and the barriers to teaching. This research illuminated actual and perceived time to teach and available resources including physical space to enable students to interact with patients were important.

Time to teach was theorised to be an actual lack of time or perceived as such by the clinical teacher. Both these contexts are highly influenced by competing pressures of teaching, the healthcare system and ensuring patient safety is maintained (Wearne et al., 2012). As pressure on healthcare increases, these competing interests become more impactful on effectiveness of clinical teaching. Time to teach is so important, that regardless of the motivation of the clinical teacher, effective teaching is very likely to be hindered by the clinical load (Dahlstrom et al., 2005). Active participation in CR tasks was viewed to be important for CR development but a barrier to enabling students to engage in this activity was lack of physical space. This context again highlights that education in the clinical setting is often not prioritized and the infrastructure in healthcare is designed with patient care rather than education in mind. In order for teaching to occur in a clinical setting, it has to be appropriate for education and teaching, including the availability of clinic rooms or space in ward environments (Dahlstrom et al., 2005).

Despite the barriers, motivation to teaching remains a key attribute of effective clinical teachers, so improving the motivation of teachers is a step towards improvement in CR development where learning is contingent on this important context. Several studies have described courses or faculty development to improve the teaching skills and knowledge of doctors (Godfrey et al., 2004, McLeod et al., 2008, Foster and Laurent, 2013). Whilst all of these cited articles report positive outcomes in terms of pedagogic knowledge and reported positive impact on teaching skills, it was only assumed that the

interventions would improve teachers' motivation (Foster and Laurent, 2013). Clinical teachers may feel compelled to teach despite lacking motivation or interest as this is required of them in their institutions (Dahlstrom et al., 2005). When coupling this with the challenges of teaching alongside the patient agenda, this promotes the call for educational establishments to have teachers specifically employed for teaching rather than patient care. Given the level of expertise of the teacher was found to be less impactful on teaching effectiveness compared with teacher motivation, this research supports programmes of clinical teaching fellows (CTFs) to support undergraduate clinical teaching (Furmedge et al., 2013, Marriott and Boyd, 2020). CTFs are generally doctors within the first few years of graduation and those who seek employment in these posts generally have interest in teaching and advancing their skills (Couchman et al., 2022) by virtue that these posts are not mandated by postgraduate training programmes. Whilst CTF posts are becoming increasingly more common and popular (Couchman et al., 2022), they are not always available in all clinical settings where medical students are taught. Where CTFs are not available in clinical settings, this research supports only including teaching in job plans where clinicians are motivated to teach. This will hopefully ensure those teachers are adequately remunerated and receive adequate time aside from their clinical commitments. Where clinical teachers are expected to teach, attention should be paid to their motivation and efforts made to ensure infrastructure is appropriate for teaching and where possible, teaching time protected to avoid the conflict of interest imposed by prioritisation of patient care. In addition, organisations should be aware that good doctors are not automatically good teachers (Harden and Laidlaw, 2012) and efforts made to ensure clinical teachers are kept up to date with evidence based education instructional techniques.

Recommendations for educational policy

Previous sections have noted how individualising education, developing students as learners, and optimising education in the clinical setting are all important to aid CR development. We now consider the importance of wider educational policy.

Curricula and training reform

A curriculum is more than a list of learning objectives or content to be covered (Grant, 2010), but instead is a comprehensive statement of all aspects of the educational programme, including the syllabus (the content), the expected methods of instruction, the organisation of the programme and detail about the assessment methods (Grant, 2010). A universities' medical school curriculum therefore determines the way in which teaching is delivered, how students approach learning and direct how learning is assessed (Harden and Laidlaw, 2012). There has been a call for CR to be developed within a spiral curriculum design (Cooper et al., 2021) which advocates revisiting of topics or themes throughout the learning process ensuring that new learning relates back to previous learning, with increasing level of difficulty as the learner develops competence (Harden, 1999). This research finds that as students develop competence, not only should the difficulty of tasks relative to that competence be increased, different methods of instruction are also required. This is supported by the literature that methods of instruction used for novices are known to have deleterious effects when applied to experts (Kalyuga et al., 2003). Whilst most medical students are not experts in any field, this research finds that a similar 'expertise reversal effect' (Kalyuga et al., 2003) is seen when students with higher clinical domain knowledge are faced with the instructional techniques used for novices. It has been discussed previously, that building a

relationship with students and aiming to individualise their education would have positive impact on their CR development through appropriately targeted interventions. The curriculum has a role in aiding teachers to be better able to make these judgements, and this is discussed in this section.

Continuity, or the lack of, in medical education is an issue that makes it very challenging for medical educators to make judgements about a student's knowledge, skills or ability (Englander and Carraccio, 2018). Individualisation of education is important for CR development and individualisation of education is only possible once teachers have an understanding of a student's ability and needs (Harden and Laidlaw, 2012, Lee and Ross, 2021). Additionally, continuity is required to ensure development of relationships between the teacher and student to enable individualisation. Specifically, this research found that when student-teacher relationships are formed, teachers are better able to understand their students' requirements and pre-existing abilities and students feel more confident to engage with CR tasks and feel at ease to ask questions to aid their understanding. Therefore, we must consider how we should structure education through the curriculum to make continuity and forming of teacher-student relationships a priority. Longitudinal Integrated Clerkships (LICs) have been advocated as a way of achieving these goals (Teherani et al., 2013, Englander and Carraccio, 2018, Lee and Ross, 2021).

LICs serve as an alternative to traditional block, rotational placements that are commonplace in clinical education in the UK (Teherani et al., 2013, Brown et al., 2019). Block, rotational clinical attachments see students moving through different clinical specialties and sometimes this rotation is rapid with the time spent in a particular specialty being less than 2 weeks. When clinical attachments ate delivered in this way, there is insufficient time to build relationships with teachers (Teherani et al., 2013). Additionally, a 'blocked' approach to education is not supported by cognitive science which would

support a mixed approach to learning (Brown et al., 2014, Bartlett and Muir, 2018). LICs offer students the ability to spend longer time and, therefore, benefit from the continuity that results from continued exposure to the same clinical setting including continuity with teachers, patients and their peers (Brown et al., 2019). Relevant to this research is the positive impact that LICs could have on the teacher-student relationship and the subsequent impact on CR development.

LICs have been shown to enable a continuous student-teacher relationship (Ogur et al., 2007) which in turn enables "serial, iterative assessment from a variety of perspectives" (Ogur et al., 2007). Therefore, the continuity derived from the LIC enables teachers to understand their students' knowledge and requirements and would enable individualisation of students' education (Walters et al., 2012, Bartlett and Muir, 2018). Students' rate LICs highly when compared with traditional block placements (Teherani et al., 2013) and evidence suggests that students exposed to LICs perform as well, or better than those who have experienced traditional placements. LICs have established pedagogical advantages (Walters et al., 2012) and although literature pertaining to the development of CR through LICs is limited, what is available supports CR development through longitudinal approaches (Duca and Glod, 2019, Rowat and Suneja, 2022, Singh et al., 2022).

However, LICs, whilst gaining popularity (Worley et al., 2016), only constitute a small proportion of clinical attachments globally (Brown et al., 2019) and whilst guidance is available on implementation (Ellaway et al., 2013) challenges have been reported (Heddle et al., 2014). Successful implementation is possible (Bartlett et al., 2019) and several UK medical schools have adopted the LIC approach within their clinical curricula (Brown et al., 2019). Where an LIC approach is not adopted, CR can still be integrated as a spiral, longitudinal aspect of the curriculum (Singh et al., 2022) which, at the

time of this research, was being developed in the Medical School where this research was undertaken, the University of Nottingham. An LIC approach, whilst not common in UK medical education, is gaining traction and is founded in sound educational evidence and may provide reform required to make medical education more effective and sustainable. Sustainability in healthcare education is important, including ensuring sufficient numbers of students and trainees.

Given the shortfall in medical graduates and therefore compounding the workforce crisis in the NHS (MSC, 2021), innovative approaches to medical training are being considered such as medical apprenticeships. Medical apprenticeships were confirmed as 'approved' in 2022 (NHS, 2022) with the primary drive for their creation seemingly based in the requirement for widening participation and encouraging training of doctors where they would not have considered a medical degree due to financial or personal reasons (HEE, 2022). Although concerns have been raised regarding the ability of these programmes to ensure the same level of excellence as traditional programmes (BMA, 2022), viewing medical training as an apprenticeship is not new. In fact, the basis of clinical attachments and learning from experience and patients, is based in an apprenticeship model (Harden and Laidlaw, 2012). In this way, the apprenticeship model of obtaining a medical degree is established in sound pedagogical evidence although the exact structure these programmes will take is unknown, with no apprenticeships currently advertised and commencement not likely until 2023 at the earliest. Overall, this research supports the notion of medical apprenticeships provided they enable continuity and individualisation of education.

Medical apprenticeships offer the ability to train without candidates leaving their current NHS job (HEE, 2022). The value of learning in the workplace is well established and this research also demonstrated that when

students were confident or had experience of working in the clinical environment they were more able to engage, increasing their opportunities to develop CR. Clinical experience would be mandated in those candidates pursuing a medical apprenticeship, which as this research demonstrates, bestows upon them the benefit of lower extraneous cognitive load (Young et al., 2014) in the clinical setting, enabling more attention to be paid to the educational tasks. In current medical education, this research would therefore support approaches to improving students' confidence in the clinical setting.

Early years clinical experiences (ECE) in the pre-clinical years of training have been integrated and established into curricula across the UK (Dornan et al., 2006). The aims of ECE are varied and include enabling the integration of biomedical with clinical knowledge, understanding patients' perspectives and the social impact of disease, learning basic clinical skills and learning about the health organisation (Yardley et al., 2010) and developing confidence to aid future interactions with patients (Dornan and Bundy, 2004, Dornan et al., 2006). Given that confidence to engage with clinical encounters is important for CR development, attempts to improve students' confidence in the clinical setting is important. However, evidence that students gain confidence from ECE is limited, with the development of confidence from these encounters being described as speculative (Dornan, 2004). ECE programmes that do not focus on confidence building in the clinical setting or those that do not enable students to spend sufficient time in the clinical setting, will be unlikely to develop students' confidence in the longer term, such that it has a meaningful impact on their later encounters in the clinical environment and on CR development. Educational programmes have been developed to build confidence in the clinical setting such as those that require students to spend time as healthcare assistants (HCAs) (Walker et al., 2017, Davison et al., 2021).

HCAs have roles for the basic caring duties for patients such as toileting, manual handling and in providing comfort to patients by listening and holding hands (Davison et al., 2021). HCAs are valued members of the healthcare team who legitimately participate and excel in patient centred care (Davison and Lindqvist, 2020). Medical students often feel lacking in a role in the clinical environment (Walker et al., 2017) which may contribute to their inability to engage effectively with confidence in the clinical setting. Reports of medical students working as HCAs have increased following the COVID-19 pandemic, all of which report positively on the experience of working as an HCA on their medical student studies (Ralston and Walsh, 2017, Mitchell et al., 2020, Round, 2020). The impact of working as a HCA on students medical studies has been described as becoming "ward smart" (Walker et al., 2017), that is feeling more confident and at ease in the clinical setting which enables learning. These reports corroborate the findings of this research that confidence to engage meaningfully with opportunities to develop CR in the clinical environment are important. Programmes which encourage students to, or integrate programmes of, working as HCAs in their medical curricula are likely to contribute positively by helping medical students feel more confident (Davison et al., 2021), legitimate and useful in the clinical environment.

Aligning assessment with practice

It has long been established that assessment and a desire to pass assessment contributes significantly to students' motivation (Newble and Jaeger, 1983, Wormald et al., 2009). This research demonstrated that students were less inclined to engage in the clinical environment and the opportunities that were afforded them when they perceived their assessment practices to value factual recall rather than application of knowledge and reasoning. This finding is supported by the literature that posits "when assessments value recall, students are discouraged from reasoning at all" (Ramsden, 1992, Sefton

et al., 2008). This research also noted a reduced clinical environment engagement when students' examinations were imminent suggestive that they did not value learning in the clinical environment as effective preparation towards passing the assessments. Even students who demonstrated a mastery goal orientation or valued the goal of medical education towards becoming a doctor, those who would normally appreciate the value of learning and practising CR with real patients, were less engaged when the pressures of summative assessments drew closer. Whilst one can appreciate the students' choices to place greater emphasis on passing the exams given that progression is dependent on the results, we must question why students do not feel that learning in the clinical setting will enable passing assessments, particularly as assessments are designed to imitate clinical practice and specific value is placed on application of knowledge. What is it about learning in the clinical environment that makes students devalue it as a learning exercise to help them pass the examinations that should be assessing their ability to perform safely in this very setting?

Medical school assessments to capture clinical competence have extensively adopted Objective Structured Clinical Examinations (OSCEs) including in the organisation in which this research was conducted. OSCEs are designed to be more reliable than unstructured observations of students in the clinical setting (Boursicot et al., 2010), also known as 'long cases' (Ponnamperuma et al., 2009) and can be meticulously planned to ensure reliability, validity and fairness of the test. Despite OSCEs being widely accepted in all levels of medical education including postgraduate education, the effect on learning remains important to consider (Boursicot et al., 2010). OSCEs have been criticised when they attempt to be so objective and structured using checklists, resulting in students favouring recall rather than deep learning and application of knowledge (Gormley, 2011) resulting in the recommendation that OSCEs use global measure of competence where possible (Pell et al., 2010) to reduce this unintentional impact on student learning behaviours. Despite

this change to OSCE procedures, there remain concerns about OSCEs or other assessment methods and their effects on student engagement and learning when they are not aligned with clinical practice (Brown et al., 2019).

Within clinical practice patients are becoming more complex, and medicine has long been an inherently uncertain, complex and ambiguous environment in which to practice and learn. (Luther and Crandall, 2011, Cooke and Lemay, 2017). Medical students today are exposed to this uncertainty in the clinical environment. This poses challenges for education especially when students may not cope well with uncertainty or ambiguity in the clinical environment (White and Williams, 2017), hereafter referred to as clinical uncertainty. This research demonstrated that only students felt to have adequately high levels self-confidence and experience would develop CR from exposure to clinical uncertainty. Those with lower self-confidence or experience would be more confused by educational interventions that demonstrated clinical uncertainty, illuminating the requirement for teachers to understand their students' requirements and individualise learning. Participants also stated that imminency of assessments would impact whether teachers would offer cases highlighting clinical uncertainty and whether students would engage with them, due to a perception that these uncertain cases would not help them pass assessments. These findings demonstrate that the assessment processes do not incorporate clinical uncertainty despite knowledge that assessments aim to be aligned with practice (Boursicot et al., 2010) and that clinical uncertainty is so common (White and Williams, 2017). Whilst this research can only comment on the practices at the University where participants worked and studied, evidence from the literature suggests that clinical uncertainty is rarely incorporated into assessments (Cooke and Lemay, 2017).

Clinical uncertainty has been described as ubiquitous in medical practice (Luther and Crandall, 2011, Richmond, 2022) and intolerance of uncertainty is associated with overuse of resources, psychological distress and burnout in physicians (Luther and Crandall, 2011, Stephens et al., 2022). Clinical uncertainty is therefore important for students to be aware of, yet studies have demonstrated students are less aware of clinical uncertainty, reporting higher levels of educational uncertainty, that is how to learn, rather than uncertainty related to clinical cases or patients (Stephens et al., 2022). Students may be relatively unaware of clinical uncertainty as they are sheltered from uncertainty by educational processes that imply there is always a 'correct' answer to be found (Durning et al., 2015b, Richmond, 2022), despite the evidence to the contrary with real patients. Assessment processes, where there is a correct or incorrect response, reinforce absence of clinical uncertainty and, in so doing, decrease motivation to learn with uncertain cases (Cooke and Lemay, 2017). This may inadvertently encourage disengagement from the inherently uncertain clinical environment (Ilgen et al., 2016) which reduces opportunities for CR development. Furthermore, where assessments do not acknowledge the realities of real practice, this risks reinforcing a performance rather than a mastery goal orientation, reducing CR development that could be developed through experience. This interpretation provides an explanation for why students and teachers actively avoid cases of clinical uncertainty when assessments are imminent and why students may disengage with the clinical environment. The uncertain clinical environment is not aligned with the certain expectations of assessment.

To attend to this issue, this research supports calls to integrate, or at least acknowledge, clinical uncertainty in assessment processes (Durning et al., 2015b, Cooke and Lemay, 2017). Assessments frequently require diagnosis as an output of CR, and diagnosis is seen as a reflection of the accuracy of that process. However, diagnosis is only an intermediary and potentially unessential part of CR, where patient management is still required despite the potential

uncertainty of diagnosis (Ilgen et al., 2016, Cook et al., 2018). Removal of the requirement to provide a diagnosis would acknowledge that clinical uncertainty exists, and that action is required despite that uncertainty (Ilgen et al., 2019). Where a diagnosis is assimilated, it is entirely reasonable to have more than one correct answer which is reflective of "clinical reality" (Cooke and Lemay, 2017). This would be supported by assessments that require students to provide differential diagnoses and by assessing students' rationale for their decisions thereby gaining insight into and assessing CR process (Ten Cate, 2018). Extensive research into CR assessment has demonstrated that there is no single way to assess CR, and a combination of methods is likely to be most effective (Rencic et al., 2016). In written assessments, multiple choice questions (MCQs) or single best answer questions (SBAs) usually have single, acceptable answers which do not best represent clinical uncertainty. Script concordance testing (SCT) has been advocated as a method of assessing CR by assessing how closely a student is able to interpret clinical data compared with a clinical domain expert (Rencic et al., 2016) . SCT is advocated to account for the realities of a real life encounter and therefore uncertainty (Lubarsky et al., 2013) but has met criticism regarding validity and is not incorporated into many summative assessment procedures. More innovative methods of CR assessment include the case based clinical reasoning test (Ten Cate, 2018) and clinical prioritisation questions (Sam et al., 2020), both of which are noted here as they acknowledge and accept clinical uncertainty. Research is still ongoing regarding the most effective way to incorporate clinical uncertainty in CR assessment, but this research supports the effort.

Clinical uncertainty is naturally incorporated where assessments are conducted in the clinical environment. Criticism of 'long cases' as being able to provide standardised and reliable assessments of medical students (Boursicot et al., 2010) resulted in almost universal integration of OSCE assessments. However, maintaining a holistic view towards the patient (Ponnamperuma et al., 2009), incorporation of clinical uncertainty and the ability to conduct an

assessment of CR in a clinical context remain advantages of long-cases. Context has been shown to be a core component of CR (Daniel M et al., 2019), both as a process and various contexts impact educational development as shown in this research. Context also impacts assessment of CR leading to recommendations that CR should be assessed in multiple contexts to increase validity and reliability of those assessments (Rencic et al., 2016). Workplace Based Assessments (WBAs) such as the mini- clinical evaluation exercise (mini-CEX) or case based discussion (CBD) are utilised widely in postgraduate medical education (PGME) and have been described for their utility in CR assessment (Rencic et al., 2016). WBAs have the advantage of occurring in the clinical setting and therefore may be able to embrace clinical context but have disadvantages of not being structured and requiring significantly greater assessment time. When WBAs are utilised for assessment, aligning them with the curriculum is important. Structured learning outcomes to be achieved for example will not be best assessed by WBAs where the case selection is more unpredictable. Lessons from PGME, and recent changes to PG speciality training curricula to incorporate higher level outcomes rather than related to a specific disease, highlight the importance of acknowledging learning in the clinical setting and allowing trainees more control over their learning, reinforcing the drive towards mastery rather than performance goals. These changes may have similar benefits for UGME but, if learning outcomes are too vague, may have unintended consequences for novice students who don't know anything about what is to be learned in a particular domain. This is an area that requires further research.

Overall, no single way of assessing CR is superior and a combination is likely to be most effective. Whichever way organisations choose to assess CR, what is clear from this research is that acknowledging clinical uncertainty through educational processes which are aligned with assessment is important to promote motivation, engagement and CR development. Where clinical uncertainty is acknowledged in assessments and for those students who have

developed adequate knowledge, confidence and experience in the clinical domain, introduction of clinical uncertainty may assist development of CR which further aids uncertainty tolerance (Richmond, 2022).

Summary of recommendations for policy and practice

Figure 20 reinforces the recommendations derived from this research for the student, teacher, curricula and educational organisations.

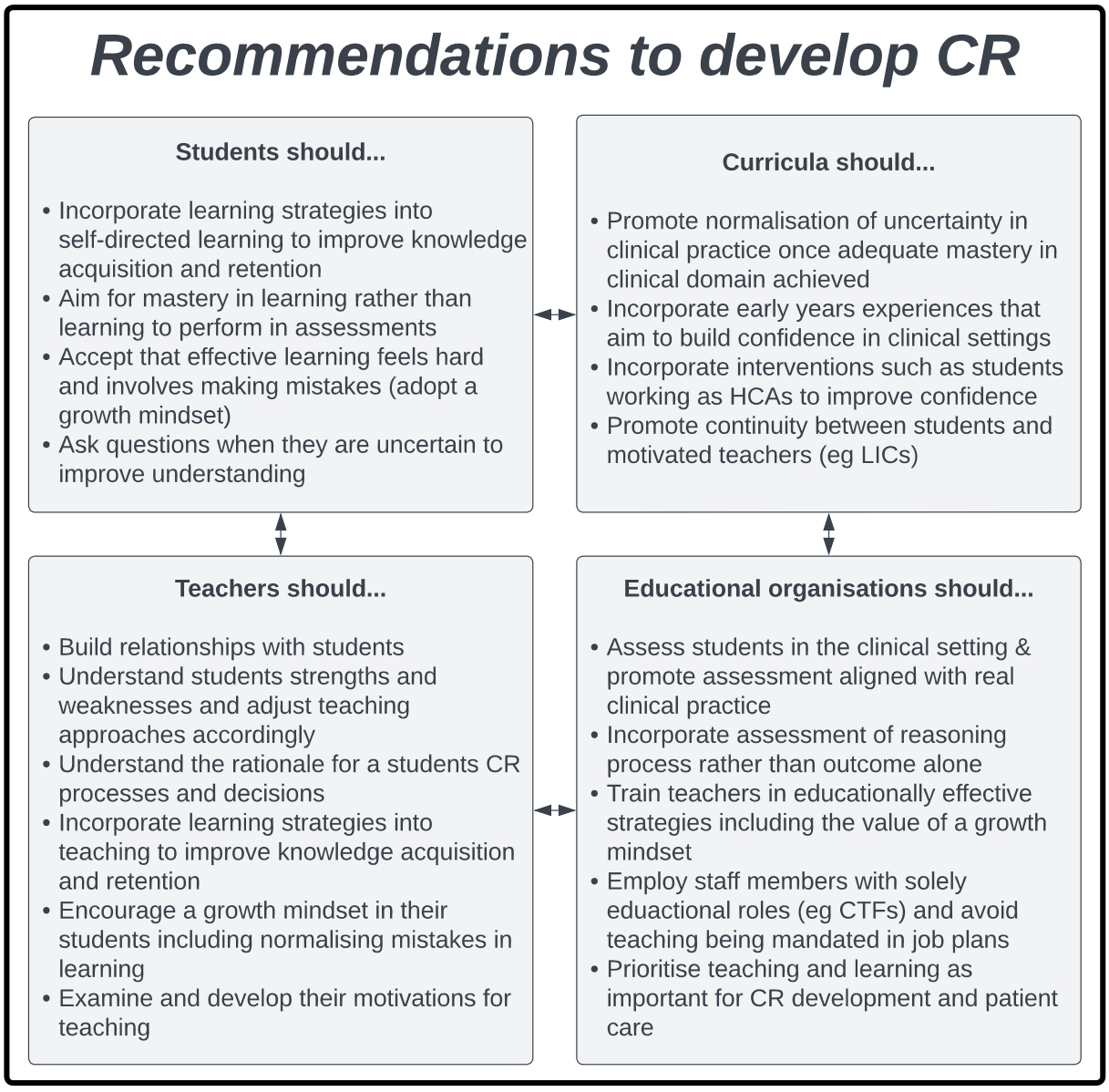

Figure 20: Recommendations to improve CR through educational practice and policy

Recommendations for further research

This research has been deliberately exploratory and the CMOCs are individual theories or hypotheses, each of which could be explored through further research. The following section will consider the specific areas this researcher deems particularly important for advancement of knowledge in this field or for the development of CR education to continue the ambition towards improving CR to improve patient care (Graber et al., 2018).

Much of CR research has been conducted in context devoid, experimental settings but as this research has alluded and focused on, context is not something that can be limited in real life CR. The call for CR research to be undertaken 'in the wild' (Gruppen and Frohna, 2002) is not new but this research suggests the evaluation of the development of CR needs to similarly consider context with upmost importance (Torre et al., 2020). In fact, research approaches that do not consider the contexts that impact their interventions are greatly reducing the potential transferability to educational practice. Research to investigate CR processes in real clinical situations using ethnography has been described (Chopra, 2020) and a similar approach could be utilised as a method alongside realist or other qualitative approaches and methods to understand CR development through education. This would be valuable particularly when evaluating both currently accepted educational approaches and newer innovations. In this research, although not formally used as a method, the researcher was a clinical teacher alongside the research project which enabled insight into what was happening during various educational interventions to develop CR though their own experience and through informal conversations with medical students. On reflection, this is a form of ethnography as the researcher was able to gain insight from their observations.

Uncertainty is ubiquitous in clinical practice and this research has found that uncertainty and complexity likely have a role in CR development once a certain level of knowledge, confidence and clinical experience has been attained. What is unknown is the point at which teachers can deem students ready to tolerate uncertainty effectively, to lead to educational gains rather than causing confusion, distress and potential loss of engagement. It is unlikely there is a magic switch when a student becomes ready, more likely this readiness occurs over time and at varying rates dependent on the clinical domain. In order to expect engagement rather an avoidance of cases which incorporate uncertainty (Geller, 2013), tolerance for uncertainty is required. Research in the development of uncertainty tolerance is increasing (Simpkin and Schwartzstein, 2016, Papanagnou et al., 2021) and more research investigating how to develop uncertainty tolerance in students to better enable CR development are called for (Luther and Crandall, 2011, Papanagnou et al., 2021). It is also unknown whether incorporating uncertainty and complexity is required at an undergraduate level or whether this would be better retained in postgraduate education. Additionally, if uncertainty is incorporated into assessments to align them with real life clinical practice, we need to know whether this translates into higher engagement in clinical settings and the subsequent development of CR that is expected from more opportunities, as postulated by this research.

This research was deliberately exploratory but further research into CR development needs to consider context alongside the evaluation of educational interventions, as well as which interventions are likely to work and which are not. A focus group was conducted in this research but due to researcher inexperience in realist approaches, was found to be a challenging way of elucidating deeper understanding. As research experience has developed and on reflection of a recent paper on the use of focus groups in

realist evaluation (Manzano, 2022), the potential value of this method of evaluation of CR development is more evident. This research utilised a focus group with student participants only. However, conducting focus groups with heterogeneous members is more likely to be valuable in illuminating contexts which impact the outcomes (Manzano, 2022). In this research, conducting focus groups with students, teachers and faculty together was initially felt to be detrimental due to the potential hierarchy between the groups and concern over silencing of the students' opinions. However, where a researcher is aware of these issues, adjudicates between members appropriately and participants are open to honest discussion, these apprehensions may be unfounded. In fact, open and interested faculty members and clinical teachers hearing the direct experiences of multiple students may enable students to provide more candid accounts of when educational experiences have not been valuable and discussion over the potential mechanisms and reasons for this outcome from varying perspectives. The use of focus groups in realist research within medical education is likely to be valuable at identifying contexts at different levels provided the researcher has sufficient experience and adequate prior understanding of the intervention under evaluation.

This thesis has noted the difficulty in measuring CR for the purposes of research, in assessment and in determining the most effective educational interventions. This issue of measurement has been described by Rencic et al (2016) asking, "How do we assess clinical reasoning under conditions of diagnostic uncertainty given that there is no gold standard for assessing the clinical reasoning process?". Some studies have used functional MRI (fMRI) to investigate the neural pathways involved in CR processes and the differences between novices and experts (Durning et al., 2015a, Chang et al., 2016). There may be a role of fMRI in CR development research to enable visualization of when a student is utilising pathways associated with NAR and correlating this with both accuracy of CR through diagnosis or management and in the correlation between a teacher's perception of a student's level of knowledge.

Research here is vital to determine teacher accuracy when assessing students' knowledge, which enables them to appropriately allow the use of NAR when students are deemed to have sufficient knowledge. fMRI may also prove useful in providing quantitative evidence supporting the switch from NAR to AR processes in CR, enabling a deeper understanding of the process of CR and therefore more information to develop educational interventions.

The research has noted that there is a relationship between knowledge, confidence and engagement in CR tasks or other educational opportunities. It is theorised that when a student's confidence in their knowledge is higher, this allows them to engage with more confidence, enabling greater opportunities to engage with various educational opportunities thus increasing knowledge and therefore confidence further. This reciprocal relationship was not specifically examined in this work, however, and would warrant further research to determine other factors which could affect this triad and the validity of this claim. Moreover, there is a difference between confidence to engage in tasks and the learning that this brings about, and the self-efficacy beliefs required to participate in tasks. Further research to understand the motivations of students in CR development would be valuable.

COVID-19 effect

This research commenced in 2016 but completed in 2022. During the initial part of the COVID-19 pandemic in early 2020, many medical research projects were halted entirely due to loss of researchers to clinical practice or transfer of research priorities towards COVID rather than other topics. These issues did not affect this research as the researcher was on maternity leave and the research was being conducted alongside other clinical and educational

commitments rather than full time. However, there were some effects on the research as detailed here.

During the data collection phase, the COVID-19 pandemic had affected how students were being taught. COVID-19 was not specifically focused upon during data collection, but the pandemic impacted the way in which education was delivered. More teaching was delivered virtually rather than face to face which led to virtual teaching being used more widely than prior to the pandemic. This enabled more data to be collected about the impact of virtual teaching and to theorise the educational benefit but also meant that some participants in the study had limited real life clinical experience or they drew upon previous clinical experience. Whilst not specifically focused on in this research, the transition to virtual teaching environments may be required in future due to ongoing social distancing requirements. In this case, further research is needed to ensure that any virtual teaching to develop CR takes the surrounding contexts into account to ensure that this is effective in different circumstances and for different students.

Due to legal restrictions on social contact, interviews could not be conducted in person during the pandemic but had the positive effect of enabling virtual interviews to be conducted via online platforms. This had unexpected positive effects as this was more convenient for many participants and for the researcher, which enabled multiple interviews to be conducted in one day, reduced cost and environmental impact of travel and encouraged more participants to enrol in the study. The increase in multiple platforms enabling high quality video and audio meetings and the acceptability of this method of gathering data is an ongoing potential positive effect of the pandemic (Roberts et al., 2021). Whilst not a concern in this research, some have expressed reservations about virtual interviewing replacing face to face practices (Chandratre and Soman, 2020). The potential benefits and challenges

of virtual interviewing should be considered when planning research (Roberts et al., 2021) and some may still be best conducted with established face to face techniques

Limitations

This research has some limitations which are considered here. The researcher was a novice to realist research approaches and more familiar with clinical research undertaken using quantitative methods. In the realist review, the searches were undertaken using the approach used in systematic reviews. Whilst this is accepted as a rigorous approach in realist research, it does not consider grey literature and unpublished studies. Although, through the researcher's development in realist approaches, it was evident that inclusion of these literature types would be beneficial, it was unclear initially how to locate such evidence relevant to the research. The researcher was also unclear how to perform literature searches that were underpinned by the search for theories of how and why an intervention might work. Whilst literature searching did conform to the available information to the researcher at the time (Wong et al., 2013b) information regarding how this might be done is now more apparent (Booth and Carroll, 2015, Booth et al., 2020). This led to confusion and selection of studies in the realist review that contained primarily quantitative methods and potentially contributed to the difficulty in finding evidence within these studies that related to the contexts in which the educational interventions worked or not. Selection of more high-quality qualitative studies would have likely provided more evidence here and potentially enabled development of more refined theories related to teacher level or wider organisational or educational contexts. Instead, the selected studies, only provided evidence of individual student level contexts that impacted the effectiveness of interventions. However, further exploration of other contexts was conducted in the realist evaluation.

Another limitation of the research being conducted as part of a PhD project, particularly as the PhD was conducted part-time alongside other clinical and educational commitments, included the lack of time and resources. In the realist review, further exploration of the developing theories against the evidence in an iterative fashion is recommended (Wong et al., 2013b). Further searches of the literature were performed alongside the developing theories, but additional searches could have been done if more time was available, particularly, as noted above, for studies that further reinforced the theoretical basis for educational interventions to develop CR. Within the realist evaluation, checking developing theories is advocated (Manzano, 2016) to ensure that participants views are accurately expressed in CMOCs. To an extent, this was completed with student participants through the 2 rounds of data collection, but clinical teachers and faculty were not consulted after the initial interviews to confirm or refute the developing ideas. Although student participants were consulted through 2 rounds of data collection with a period of reflection and data analysis in between, the same students were not interviewed twice, not allowing individual students a chance to refute or confirm the developing CMOCs. Further searches of the literature and interviewing participants more than once would be possible where more time and resources are available, especially within the context of realist research being conducted within larger research teams.

Funding and time restrictions meant that not all interviews were transcribed verbatim, but instead the researcher listened and made reflective notes as the data related to the developing theories. Whilst this meant that direct quotes were not available for all interviews, the nature of realist research and the fact that data is interpreted through a realist lens anyway means that this should not have reduced the quality of the overall programme theories developed.

The intermediate output of this research was the realist review. Narrative development of the programme theories have been described in publication (Richmond et al., 2020) and in more detail in these thesis. However, the main results were described using a visual representation. Whilst the visual representation is easy to read and understand, it may convey simplicity and misunderstandings about the interaction of different contexts and different educational interventions to the overall development of CR. In addition, the labelling of context, mechanism resource and response and the conceptualisation of outcome was different during this phase of the research as described in Chapters 5 and 6. As learning and development of the researcher has occurred through the PhD, it is clearer that entities or principles can be either context, mechanism or outcome, which they are labelled at a single point in time depends upon the issue or situation under examination (Westhorp, 2018).

Strengths

This research has successfully undertaken investigation of the development of CR; a complex cognitive and social process, impacted by various contexts which is developed through education, which is also a complex social intervention. The research aims therefore were challenging, investigating the development of a complex process within a complex system. The chosen research approach and methods through realist review and evaluation, allowed the research to successfully deepen understanding of this area considering the role of context. Not only is this important for research into CR development, but additionally awareness of the requirement to consider context and its impact on complex interventions is increasing (Skivington et al., 2021, Mattick et al., 2013) and this research contributes positively to this field. The limitations of the realist

review have been noted, but as the researcher developed understanding of the conceptualisation of CR and their understanding of realist research, the realist evaluation results produced rich data which was interpreted appropriately using the researcher's realist knowledge and skill. Subsequently, the refined programme theory is detailed, well synthesised and considers various relevant contexts. This programme theory provided understanding of the development of CR so that several practical recommendations for practice, policy and further research could be made from this work.

To engage with the literature regarding CR development, firstly conceptualisation of CR was required. This is a vast body of literature with different viewpoints and no single definition. Significant time and effort to assimilate the CR literature with personal and research team experience was required to ensure that the definition of CR used in this research was justified and then aligned with the educational theories felt to be pertinent to CR development. This effort enabled a coherent and structured programme of research where, hopefully, the conceptualisation of CR and its development is clear and justified to the reader.

Integration of theory into research is expected within realist approaches, as a theory led research approach but this also is a strength of the work. Mid-range theories; abstract theories which can be applied to a range of different situations (Davidoff et al., 2015), were utilised in this work at the point of development of understanding about CR development through various educational theories and theories that considered the role of context. Using theory in this way aided understanding and subsequently guided data collection, analysis and synthesis. This approach was also useful when interpreting the results of the research, for example considering how self-regulated learning theory (SRL) and theories of motivation supported the findings. In other words, theory was used throughout the research, to develop IPT, aiding interpretation of

the results and in supporting the findings relative to what is already known. Integration of mid-range theory enabled the development of a programme theory specific to CR development at Nottingham University Medical School but this also allows the results to be relevant and, whilst not generalizable, potentially transferable to other medical educational interventions.

Personal reflection

"A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress. As a consequence of comprehending a threshold concept there may thus be a transformed internal view of subject matter, subject landscape, or even world view. This transformation may be sudden or it may be protracted over a considerable period of time, with the transition to understanding proving troublesome."

(Meyer and Land, 2003)

At the beginning of this work, I was entirely novice in the areas of CR and realist approaches to research. In fact, apart from my own interest in teaching and clinical experience, I was novice within the areas of medical education and research. This meant the thresholds I needed to cross to enable this research were multiple and did not just entail the subject domain or research approach but a great deal about medical education generally, research more generally and then specifically areas pertaining to this research. Once understood, as the quote on threshold concepts attests to, so transformed was my view of research, I couldn't understand why anyone would not appreciate the absolute vital contribution of context to outcomes and therefore the necessity to study it in research.

Yet in medical research, the positivist view pervades most studies, a perspective that often infuses into medical education research (Biesta and van Braak, 2020). My medical background meant that quantitative research was most familiar to me and for a large time in this research, I was encouraged to have quantitative studies but as time passed, struggled to see how they 'fit'. After some time, I realised my struggle related to the difficulty in measuring CR itself, the multiplicity of educational interventions that contribute to CR development and the challenges accounting for context or confounding variables to 'prove' that an intervention was having the primary effect on outcome. Initially, my inexperience in research meant I perceived the reason for not making quantitative studies fit, was due to my lack of knowledge and understanding. Eventually, I came to appreciate that these issues were exactly the reasons why using a realist approach with realist qualitative methods were appropriate for this research. Realist approaches provided a way of theorising what was most likely to occur in certain situations and context was a vital part of understanding, rather than controlled for as may happen in some studies. This approach to research also takes the variety of educational interventions working together to develop CR into consideration.

A realist approach to research is challenging. The terminology used is initially inaccessible to a novice and, especially when a researcher has a positivist background, the change in thought processes can be prohibitively difficult. However, once the initial difficulties are overcome, the overall premise of realist research could be described as common-sense. Research to aid understanding of events in the real world requires an approach that makes sense of what is happening in the real world. This is the biggest advantage of realist approaches to research (Wong et al., 2012). Realist approaches have been described as "not for novices" (Pawson et al., 2004) and certainly, should this same research be undertaken now, the path would likely be less rocky.

However, in devising, planning, learning, and undertaking my own research, I have developed not just my understanding of research and ability to act independently in this respect, but my world view and appreciation of how to tackle problems when something that isn't working is transformed. I have already applied these new-found skills to small educational projects in my role as an NHS doctor and will continue to encourage others to consider the effects of contexts and imagining why something is or isn't working in the development of solutions. I hope that these skills will enable me to make improvements in education for students, post-graduate doctors in training and, in time, the patients they treat.

Conclusions

CR is a vital aspect of practice for doctors and, therefore, its development is a vital part of education. To develop CR effectively in different students, the complexity of education to develop CR needs to be understood, which this research attempts to accomplish. CR development requires a multitude of educational approaches which increase in complexity with students developing CR ability. Students need to acquire clinical domain knowledge which enables them to engage in CR tasks and discuss clinical cases. Opportunities to engage in CR tasks are created by motivated teachers and by students themselves when they are confident and have experience in the clinical environment. Students also are more likely to engage in the clinical environment when assessments are perceived to be aligned with real life practice rather than being based in factual recall of knowledge alone.

Students learn most effectively about the CR process when motivated teachers can explain their own thought processes, have time to discuss clinical cases and provide individualised feedback. Once sufficient clinical domain

knowledge is acquired, students should be encouraged to use NAR in CR. Clinical placements which promote continuity aid teachers in building relationships with students, allowing them to better form these judgments regarding students' abilities.

Teachers need to be enthusiastic, motivated to understand their students' needs and adapt and individualise their approach accordingly. Students need to engage in learning approaches known to increase long term knowledge retention which will enable more effective engagement with multiple educational interventions to develop CR. Finally, systems need to adapt, including the development of assessment practices which align with real world clinical practice including incorporating clinical uncertainty in assessment and employment of clinicians with specific teaching roles.

Overall, the current educational approach to developing CR does work most of the time, for most students. Medical education needs to be prioritised and individualised to work all the time and for all students to improve CR development through education.

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Appendices

Appendix 1: Abstract screening tool

1 – Highly relevant	Relates to an undergraduate STEMM subject AND describes an educational intervention which deliberately develops/teaches reasoning with a particular emphasis on dual processing theory (DIP) (intuition and/or analytical processing) OR Relates to an educational intervention which particularly focuses on reasoning using a DIP approach
2- Probably relevant	Describes an educational intervention which teaches reasoning which probably highlights some factors associated with DIP theory such as mentioning speed of processing. OR Relates to educational interventions which may promote DIP theory through other means such as, but not limited to, deliberate practice or knowledge acquisition/organization. OR Relates to educational interventions used in post-graduate education with a particular emphasis on DIP theory
3 –Possibly relevant	Describes some facet of teaching/learning which could inform an educational intervention which highlights DIP theory or metacognition. OR It is unclear whether an educational intervention is described but the abstract suggests the use of DIP theory in teaching undergraduate students. OR Describes an educational intervention related to developing reasoning but it is unclear if DIP theory is considered in its design. OR Describes an educational intervention which highlights DIP theory, but it is unclear if the context is undergraduate education
4 – Likely irrelevant	Does not meet above criteria

Abstracts graded as 1-3 were included for full text retrieval. Abstracts graded as 4 were excluded. Abstract screening tool adapted from (Davies et al., 2018)

Appendix 2: Bespoke data extraction form

<table>
<tr><td>First author:</td><td>Year:</td><td>Title:</td><td>Reviewer's initials: AR</td></tr>
<tr><td colspan="3">Decision Code and Reason Code</td><td>Comments/Notes (Excluded papers only)</td></tr>
<tr><td colspan="2">1 = Include

2 = Exclude [PROVIDE REASON CODE FOR 2]

DECISION CODE :

Reason</td><td colspan="2">1 = Investigate the neurochemical or neurostructural aspects of decision making only

2 = Doesn't describe an educational intervention

3 = Doesn't specifically target dual processing theory

4 = Assessment of reasoning only

5 = Children only (<18 years)

6 = Post graduate education only and no specific DIP intervention

7 = Investigates the use of decision support tools/checklists only

8 = Other (please state)

EXCLUSION REASON CODE:</td></tr>
<tr><td colspan="4">Overall summary for included papers only:</td></tr>
<tr><td colspan="4">Country:

Participants:</td></tr>
</table>

Sample size:

Study design:

Study aims/research question(s):

Details of educational intervention:

Is the educational intervention clearly described (could it be replicated)? YES/NO/NA

Are the required resources described? YES/NONA

Was a control group used? YES/NO

Was there any form of randomization between groups? YES/NO/NA

Other methods information?

Limitations:

Rigour (if empirical study):

1 – No clear conclusions can be drawn. Not significant

2 – Results ambiguous, but there appears to be a trend.

3 – Conclusions can probably be based on the results.

4 – Results are clear and very likely to be true.

5 – Results are unequivocal.

Outcomes *Kirkpatrick hierarchy (if applicable)*

Level 1 Participation

Level 2a Modification of attitudes/perceptions

Level 2b Modification of knowledge/skills

Level 3 Behavioural change practice

Level 4b Benefits to patient / clients **Details:**
Context and Mechanisms *To confirm or refute initial programme theory. Specify which are contexts (separate to the intervention) and which are mechanisms (divide into reactions of participants and resources of programme).* *Use trainee characteristics, training design and work environment as a model for contexts*
What does this paper add to our theoretical understanding of the educational interventions developing dual information processing in undergraduates?
Additional References to follow-up *(Please find and review additional references and add to database)*
Other comments *inc. questions for authors or questions to consider for realist evaluation*

Appendix 3: Realist review included papers

First author	Year	Title	Country	Educational intervention	Contexts	Mechanisms	Outcomes	Contribution to context theory (1-5)
Adams	2011	How we created virtual patient cases for primary care-based learning	UK	Online virtual patient resource	Limited exposure to real cases	Multiple iterations of common problems, non-analytical reasoning cases, demonstrates expert reasoning	Theoretical promotion of illness scripts and non-analytical reasoning	1, 3
Ark	2006	Giving learners the best of both worlds. Do clinical teachers need to guard against teaching pattern	Canada	Intervention as part of an experimental study, encouragement to use specific reasoning process	Absolute novices (psychology students)	Encouraged to use both modes of reasoning or analytical alone or non-analytical alone	Positive effect of using both modes of reasoning, no effect of analytical alone on diagnostic accuracy	1

		recognition to novices?						
Ark	2007	The benefits of flexibility – the pedagogical value of instructions to adopt multifaceted diagnostic reasoning strategies	Canada	Intervention as part of an experimental study, encouragement to use both analytical and non-analytical reasoning and contrast different diagnoses	Absolute novices (psychology students)	Explicit instructions on reasoning and strategies to contrast diagnoses, trust and understanding	Positive effect of using both modes of reasoning on diagnostic accuracy particularly when contrasting diagnoses	1, 3
Bender	2011	A novel educational tool for teaching diagnostic reasoning and laboratory data interpretations to veterinary (and medical) students	USA	Diagnostic pathfinder is an e-learning software students can use individually or in groups focussing on the interpretation of diagnostic tests in making a veterinary diagnosis	Novice/low knowledge veterinary students e-learning	Forced to provide data, analytical reasoning. Forces use of medical terms, building illness scripts and encapsulation of knowledge.	Improved examination results, theoretical promotion of illness scripts and non-analytical reasoning	1, 4, 5

						Able to make mistakes in safe environment leading to security or fear		
Blissett	2012	Should we teach using schemas? Evidence from a randomised trial.	Canada	Teaching cardiac murmurs, clinical symptom led (schema) vs traditional diagnosis led teaching	Novice medical students Simulated environment	Greater knowledge organisation, understanding of clinical presentation of disease	Higher diagnostic accuracy in the group taught using schemas/symptom led teaching	1, 3
Bloice	2014	Casebook – a virtual patient iPad application for teaching decision-making using electronic health records	Austria	An electronic case-based application derived from real cases in electronic health records	Students of multiple abilities Limited exposure to real cases	Expert thoughts revealed to students, feedback Exposure to multiple cases. Positive and negative reactions.	Theoretical promotion of illness scripts and non-analytical reasoning	2, 3, 4, 5

Borleffs	2003	Clinical reasoning theatre – a new approach to clinical reasoning education	The Netherlands	Students observe doctors consulting with patients with scheduled 'pauses' to discuss the case and the doctor's thought processes. Students can also suggest questions for the doctor to ask the patient	Medical students High and low knowledge	Expert's thoughts revealed to students Understanding, insight	Deeper understanding of the reasoning process Positive learning event	1, 2
Boshuizen	2012	What and how advanced medical students learn from reasoning through multiple cases	The Netherlands	Multiple cases based around the same underlying pathophysiological processes	Medical students of varying ability and knowledge	Multiple cases, promoting understanding and retention of knowledge	Theoretical promotion of illness scripts and non-analytical reasoning	3
Chamberland	2011	The influence of medical students' self-explanation on diagnostic performance	Canada	Taught to use self-explanation through a series of cases	Low and high knowledge students based upon their familiarity with the case	Self-explanation encourages non-analytical reasoning	Positive effect in low knowledge student Negative/no effect in the high	1, 2

							knowledge student	
Chamberland	2013	Students' self-explanations while solving unfamiliar cases: the role of biomedical knowledge	Canada	Intervention as part of an experimental study, encouragement to use self-explanation of their reasoning processes	Used more familiar or less familiar cases – high or low knowledge relative to the case	The more familiar cases drew fewer explanatory statements and more clinical knowledge, less familiar drew more basic science knowledge	Positive effect on learning. Theoretical promotion of illness scripts and non-analytical reasoning	1, 2
Chamberland	2015	Does medical students' diagnostic performance improve by observing examples of self-explanation provided by	Canada	Students listening to examples of self-explanations provided by peers and experts	Low domain specific knowledge, medical students	Expert explanations largely use non-analytical reasoning and skip steps – not cognitively congruent with the student Peer explanations	No beneficial effect to diagnostic accuracy. Infer that may not be beneficial to learning	1

		peers or experts?				may contain mistakes - confusion		
Chamberland	2015	Self-explanation in learning clinical reasoning – the added value of examples and prompts	Canada	Students listening to near-peer self-explanations with prompts to enhance the active process for the student	Low domain specific knowledge, medical students	Prompts allow active process, near-peer self-explanations are accurate and cognitively congruent with the student Students feel at ease	Improved diagnostic performance, beneficial to deeper learning	1
Coderre	2010	To Think Is Good: Querying an Initial Hypothesis Reduces Diagnostic Error in Medical Students	Canada	Intervention as part of an experimental study, encouragement to rethink diagnosis after additional information provided	Low knowledge, 1st year medical students	Enhances reflection and analytical reasoning	Improved diagnostic accuracy	1

Eva	2007	Teaching from the clinical reasoning literature: combined reasoning strategies help novice diagnosticians overcome misleading information	Canada	Intervention as part of an experimental study, encouragement to use both analytical and non-analytical reasoning	Absolute novices (undergraduate psychology students)	Using both analytical and non-analytical reasoning strategies	Improved diagnostic accuracy	1
Evered	2013	To What Extent Does Nonanalytic Reasoning Contribute to Visual Learning in Cytopathology?	UK	Taught how to diagnose cytology slides either by lists of important features or by pattern recognition alone	Novices and Highly visual domain	Using pattern recognition alone	Improved diagnostic accuracy Faster diagnosis in non-analytic group	1
Graafland	2014	A serious game can be a valid method to train clinical	The Netherlands	A serious game which focuses on the diagnosis and management of	Novice medical students (study also included experts to	Time pressured with high level of difficulty	Less accurate decisions and frustration may lead to reduced	1, 4

		decision making in surgery		patients with biliary tract disease. The cases were time pressured which suggests fast decision making was necessary	validate the game and residents also participated – not included in the review) Non-visual clinical decision making	leading to rapid decision making and frustration	engagement and motivation – negative learning experience	
Jacobson	2010	Integrated cases section, a course designed to promote clinical reasoning in year 2 medical students	USA	7-week transition Course, incorporating analytic and nonanalytic clinical reasoning models. Practice with variable case scenarios enhanced students' application of basic science knowledge to	Limited clinical experience, novices	Promoting analytical and non-analytical reasoning, promotes preparedness and understanding	Improved performance on clinical reasoning test (script concordance test) Students reported increased confidence	1

				clinical problem solving.				
Kalatunga-Moruzi	2001	Coordination of analytic and similarity-based processing strategies and expertise in dermatological diagnosis	Canada	Taught how to diagnose dermatological slides including both typical and atypical cases	Novice, pre-clinical medical students And highly visual domain (dermatological diagnosis)	Promoting non-analytical reasoning specifically (similarity-based approach)	Improved diagnostic accuracy	1
Klamen	2011	The efficacy of a targeted remediation process for students who fail standardized patient examinations	USA	A course to improve clinical reasoning in students who have failed a high stakes examination including detailed feedback and teaching to use concept maps for presentation led learning	Students may have varying levels of knowledge but have failed an exam due to clinical reasoning difficulties – one could assume either low knowledge or inability to apply it.	Detailed accurate feedback and teaching using learning strategies (concept maps)	Improved reasoning in later simulated patient encounters	1, 3

Kopp	2008	Fostering diagnostic knowledge through computer-supported, case-based worked examples – effects of erroneous examples and feedback	Germany	Intervention as part of an experimental study,	Medical students with a range of ability and knowledge	Multiple cases worked examples with errors and accurate and elaborated feedback. Understanding Positive effect of timely feedback Confusion – negative effect	Theoretical promotion of illness scripts and non-analytical reasoning	3
Linn	2012	Clinical reasoning. A guide to improving teaching and practice	Australia	Description of teaching clinical reasoning in a clinical consultation	Students have varying levels of ability	Deconstruction of the clinical reasoning process, Expert explanation of reasoning process	No outcomes specified	1, 3

Mamede	2012	Reflection as a strategy to foster medical students' acquisition of diagnostic competence	Brazil	Intervention as part of an experimental study – taught to reflect	Novice medical students	Analytical reasoning in the form of structured reflection	Improved diagnostic accuracy	1
McGregor	2012	Preparing medical students for clinical decision making: A pilot study exploring how students make decisions and the perceived impact of a clinical decision-making teaching intervention	UK	A multi-faceted educational intervention – of interest to this study was the simulated session that encourages prioritisation and attempts to induce bias by promoting an incorrect diagnosis	Experienced medical students Simulated environment Students have positive or negative coping mechanisms for stress	Positive – understanding, gratitude for the experience Negative – anxiety, fear, stress	Positive – confidence, positive learning event, preparedness for practise Negative – detracts for learning goals	2, 4, 5

Myung	2013	The effect of enhanced analytic reasoning on diagnostic accuracy – a randomised controlled study	South Korea	Experimental study – analytical reasoning enhanced by students populating a table with differential diagnoses and compatible signs	4th years students – both high and low knowledge which was case specific	Enhancing analytical reasoning – positive effect for those unfamiliar cases/ones the students had low knowledge for	Improved diagnostic accuracy for those with low knowledge, diagnostic accuracy not enhanced for those with higher knowledge of the case	1, 2
Nendaz	2012	Bringing explicit insights into cognitive psychology features during clinical reasoning seminars – a prospective, controlled study	Switzerland	Case based reasoning seminars encouraging explicit reasoning processes and self-reflection on their reasoning process	High and low knowledge medical students	Promotes non-analytical and analytical reasoning Clinical teacher makes their reasoning strategies explicit	Better differential diagnoses lists, main effect was for difficult cases for which the students had less experience and knowledge	1, 2
Pinnock	2012	evPaeds: undergraduate	New Zealand	Online paediatric clinical reasoning software,	Medical students with varying abilities	Feedback and allows mistakes in	Positive student feedback about the teaching,	1, 2, 3, 4, 5

		clinical reasoning		including expert opinions on the case and a branching design for students to make their own decisions in the management of the case	Used for pre-clinical and clinical students	safe environment, promotes both non-analytical and analytical reasoning, students realise there is consequence to their actions, promotes understanding	develops both analytical and non-analytical reasoning ability, positive learning event	
Raupach	2016	Test-enhanced learning of clinical reasoning: a crossover randomised trial	Germany	Experimental study where repeated testing with key questions was compared to repeated case led learning	Medical students with varying abilities	Understanding, more knowledge retained in long term memory	Theoretical promotion of illness scripts and non-analytical reasoning	3

Sherbino	2014	Ineffectiveness of cognitive forcing strategies to reduce biases in diagnostic reasoning: a controlled trial	Canada	Cognitive forcing strategies – seminar to encourage self-monitoring techniques and actively searching for alternative diagnoses	Experienced medical students	Enhanced analytical reasoning by actively searching for alternative diagnoses	No improvement in diagnostic accuracy	2

Appendix 4: Ethical approval

University of Nottingham
UK | CHINA | MALAYSIA

Email: FMHS-ResearchEthics@nottingham.ac.uk

Faculty of Medicine & Health Sciences
Research Ethics Committee
c/o Faculty PVC Office
School of Medicine Education Centre
B Floor, Medical School
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10 April 2019

Dr Anna Richmond
PhD Student
c/o Mr William Atiomo
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Child Health, Obstetrics & Gynaecology
School of Medicine
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Dear Dr Richmond

Ethics Reference No: 266-1903 **– please always quote**	
Study Title: Educational interventions to develop analytical and non-analytical clinical reasoning in medical students: a realist evaluation.	
Chief Investigator/Supervisor: Mr William Atiomo, Associate Professor, Child Health, Obstetrics & Gynaecology.	
Lead Investigators/student: Dr Anna Richmond, PhD, Obstetrics & Gynaecology	
Other Key Investigators: Dr Rakesh Patel, Associate Professor of Medical Education, Dr Simon Gay, Director of BM BS Education Governance and Clinical Associate Professor, Education Centre, School of Medicine	
Proposed Start Date: 01/04/2019	**Proposed End Date:** 31/10/2019

Thank you for submitting the above application and the following documents were received:

- FMHS REC Application form and supporting documents version 1.0: 20/03/2019

These have been reviewed by electronic sub-committee and are satisfactory and the study has been given a favourable opinion.

A favourable opinion has been given on the understanding that:

1. The protocol agreed is followed and the Committee is informed of any changes using a notice of amendment form (please request a form).
2. The Chair is informed of any serious or unexpected event.
3. An End of Project Progress Report is completed and returned when the study has finished (Please request a form).

Yours sincerely

Professor Ravi Mahajan
Chair, Faculty of Medicine & Health Sciences Research Ethics Committee

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Lead Investigators/student: Dr Anna Richmond, PhD, Obstetrics & Gynaecology	
Other Key Investigators: Dr Rakesh Patel, Associate Professor of Medical Education, Dr Simon Gay, Director of BM BS Education Governance and Clinical Associate Professor, Education Centre, School of Medicine	
Proposed Start Date: 01/04/2019	**Proposed End Date:** 31/08/2020

Thank you for notifying the Committee of amendment no 1: 08/07/2020 to change to online and the following documents were received:

- FMHS REC Notice of Amendment form dated 08/07/2020
- Participant Information sheet- student interviews update for online using teams 08/07/2020
- E-mail to participants- new for online 08/07/2020

These have been reviewed and are satisfactory and the above amendment is approved.

Approval is given on the understanding that:

1. The protocol agreed is followed and the Committee is informed of any changes using a notice of amendment form (please request a form).
2. The Chair is informed of any serious or unexpected event.
3. An End of Project Progress Report is completed and returned when the study has finished (Please request a form).

Yours sincerely

Dr Bethan E Phillips, Associate Professor
Clinical, Metabolic & Molecular Physiology, Medical Sciences & Graduate Entry Medicine
Acting Chair, Faculty of Medicine & Health Sciences Research Ethics Committee

Appendix 5: Participant information leaflet – student version

Study Title: How do individual factors/contexts affect medical student's reactions or responses when exposed to various educational situations to develop their clinical reasoning ability?

PARTICIPANT INFORMATION SHEET

Research Ethics Reference: 266-1903

Version 1.1 Date: 01/07/2020

We would like to invite you to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read this carefully and discuss it with others if you wish. Ask us anything that is not clear.

What is the purpose of the research?

This research study is part of a wider project to gain deeper understanding into the factors that affect educational interventions aiming at developing clinical reasoning ability in medical students. This is an important skill that is associated with forming diagnoses and management plans for patients. The clinical reasoning process is complex but for this research focuses on the development of analytical (slow, thorough reasoning) and non-analytical reasoning (rapid, intuitive reasoning). Both types of thinking are important for safe and effective doctors. This study aims to understanding your views and experiences of various educational activities, teaching or experiences that may work to develop your clinical reasoning and decision-making processes.

Why have I been invited to take part?

You have been invited to take part in this research because you are a medical student who has been involved in educational interventions that aim to develop your clinical reasoning ability.

We will be recruiting up to 15 participants in this study.

Do I have to take part?

No. It is up to you to decide if you want to take part in this research. We will describe the study and go through this information sheet with you to answer any questions you may have. If you agree to participate, we will ask you to sign a consent form using Microsoft forms (a link to this will be sent to you). However, you would still be free to withdraw from the study at any time, without giving a reason and without any negative consequences, by advising the researchers of this decision. This would not affect your legal rights. If you are a student at the University of Nottingham, there would be no disadvantages to your study or to you personally if you decide not to take part in this study, or if you decide to withdraw at any point.

What will happen to me if I take part?

A researcher sends you the information sheet which explain the procedures. If you agree to take part in the study, you will:

Be sent an electronic consent form to complete on Microsoft Forms.

Following provision of consent, you will be invited to attend an online interview on Microsoft Teams, lasting around an hour. The interview will be held at a mutually convenient time for both you and the researcher.

Microsoft Teams has the functionality to video-audio record the interview. The recording through Microsoft Teams is to support audio quality, rather than for analysis purposes. All participants will initially be able to access the recording (until the settings are changed by the researcher), so you are asked to please not do so. If you do not wish to be video-audio recorded, please inform the researcher before the interview and it will proceed with audio recording only.

The study will involve an interview related to your own experiences of teaching and education to develop your clinical reasoning skills. These may be teaching sessions that are clearly signposted as aiming to develop clinical reasoning skills. Other clinical experiences may be less clear as aiming to developing reasoning but are also important to discuss. The researcher will at times offer suggestions of situations that may develop clinical reasoning ability and you will have a chance to give your opinion.

What is an interview and what is realist research?

This is a qualitative research technique which aims to build understanding of your experience through a one-to-one discussion. The study uses a type of research called realist research. This is a way of understanding how wider factors affect interventions to bring about an outcome. In this case we are interested in understanding your experience of various educational activities, any factors that may have affected their educational benefit and why this was the case.

Are there any risks in taking part?

There are no anticipated risks from participation.

Are there any benefits in taking part?

A potential benefit of taking part is your personal understanding of the clinical reasoning process and situations that may assist this development may improve. However, this is not the aim of this study.

Will my time/travel costs be reimbursed?

Participants will not receive an inconvenience allowance to participate in this study.

What happens to the data provided?

The interview will be audio recorded and later transcribed for further analysis. The research data will be stored confidentially using NVivo and Excel software. To help ensure your privacy, you will be assigned a volunteer study identification number (for example P01 for participant number 1), and it will be used instead of your name. We will save all the recordings and research data using that volunteer study identification number so that none of the data will have your real name or other individual identifiers associated with them. Your name and any information about you will not be disclosed outside the study centre.

Personal / sensitive data will not be required.

The researcher and/or e.g., research team, supervisor and any transcription services will have access to research data.

We would like your permission to use fully anonymised direct quotes in research publications.

All research data and records will be stored for a minimum of 7 years after publication or public release of the work of the research.

What will happen if I don't want to carry on with the study?

Even after you have signed the consent form, you are free to withdraw from the study at any time without giving any reason and without your legal rights being affected. Any personal data will be destroyed.

Who will know that I am taking part in this research?

All information collected about you during this research would be kept strictly confidential. Any imaging and electronic data will be anonymised with a code as detailed above. All such data are kept on password-protected databases sitting on a restricted access computer system and any paper information (such as your consent form, contact details and any research questionnaires) would be stored safely in lockable cabinets in a swipe-card secured building and would only be accessed by the research team.

Under UK Data Protection laws, the University is the Data Controller (legally responsible for the data security), and the Chief Investigator of this study (named above) is the Data Custodian (manages access to the data). This means we are responsible for looking after your information and using it properly. Your rights to access, change or move your information are limited as we need to manage your information in specific ways to comply with certain laws and for the research to be reliable and accurate. To safeguard your rights, we will use the minimum personally – identifiable information possible.

You can find out more about how we use your information and to read our privacy notice at:

https://www.nottingham.ac.uk/utilities/privacy.aspx/

Designated individuals of the University of Nottingham may be given access to data for monitoring and/or audit of the study to ensure we are complying with guidelines.

Anything you say during an interview will be kept confidential, unless you reveal something of concern that may put yourself or anyone else at risk. It will then be necessary to report to the appropriate persons. If this is a clinical concern, it would be reported to the consultant lead of that clinical area. If the concern relates to the medical school or medical education, it would be reported to the Dean of medical education at the University of Nottingham.

What will happen to the results of the research?

The research may be published in a medical education journal. The research will be written up as dissertation for the degree of PhD.

The research will be written up as a thesis. On successful submission of the thesis, it will be deposited both in print and online in the University archives, to facilitate its use in future research.

Who has reviewed this study?

All research involving people is looked at by an independent group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and given favourable opinion by the Faculty of Medicine and Health Sciences Research Ethics Committee (Reference number: FMHS 266-1903)

Who is organising and funding the research?

The lead researcher is part funded by Nottingham University NHS Trust.

What if something goes wrong?

If you have a concern about any aspect of this project, please speak to the researcher (Dr Anna Richmond) who will do their best to answer your query. The researcher should acknowledge your concern within 10 working days and give you an indication of how he/she intends to deal with it. If you remain unhappy and wish to complain formally, you can do this by contacting the FMHS Research Ethics Committee Administrator, Faculty Hub - Medicine & Health

Sciences, E14, E Floor, Medical School, Queen's Medical Centre Campus, Nottingham University Hospitals, Nottingham, NG7 2UH.

E-mail: FMHS-ResearchEthics@nottingham.ac.uk.

Contact Details

If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact:

Dr Anna Richmond

Medical Education Centre

B90b, Medical School, University of Nottingham, Queens Medical Centre

Tel: 07840 469346

Email: anna.richmond@nottingham.ac.uk

Appendix 6: Example interview guide – student version

- Introduction and purpose – how various contexts affect educational interventions or activities in developing CR ability and why. Give examples as much as possible.
- What do you think clinical reasoning is?

Key interventions: **Explicitly ask students if they have experienced…**

Being told to use analytical reasoning inc. self-explanation	Simulated patient encounters
Being told to use non-analytical reasoning including forcing time pressure	Real experiences on wards
Observation of experts reasoning	Explanation of expert thought process
Observation of peers/near-peers	Explanation of peer thought process
Feedback of CR ability – what specific feedback do they get	Explanation of near peer thought process e.g., CTF's
General strategies to improve knowledge	Teaching about the reasoning process
Worked cases/serial cue cases – case led teaching sessions	Case discussions with educators, contrasting possibilities of diagnoses and management
Virtual patients and cases	Practicing clinical reasoning with real patients

Exploring questions for each intervention that participant has experienced:

- Clinical or specific examples
- What was it about this intervention that helped develop CR or not?
- Why did it work/not work for you?
- What other ways develop your decision making? How could this be facilitated?
- So, you are saying that...'in A situation, you have found B intervention helpful because it promotes C? Do you find it different in X circumstance?

- Much of development of reasoning occurs through participating in clinical reasoning tasks and you must have knowledge to be able to practice. So, there is an idea that what you already know is the most important factor in determining teaching effectiveness? Does this resonate with your experience? Any examples?
- Simulated environments are increasingly used to allow reasoning practice. There is an idea that your ability to cope and confidence level has an impact on how well you learn in simulated environments? How would you describe your self-confidence? Does this impact your learning? How? Any examples?
- There is an idea that educators offer you different experiences or activities based on their impression of your knowledge, motivation, or interest/enthusiasm – is that something that has affected you? How?
- Time and space in the clinical environment affect your opportunities to practice in clinical attachment – has that been your experience?
- Assessments drive learning and the preoccupation with exams takes students away from spending time on the wards and clinical areas even though this is needed to build breadth of experience and reasoning ability – do you agree with this? Why?

To finish:

- If you could think of the perfect way for clinical reasoning to be taught to you, what would you like?
- Do you have any other points to discuss? Please contact me if you think of anything.

Appendix 7: Participant consent form – student version

Participants Consent Form

Final version 1.0: 16.01.2019

Title of Study: How do individual factors/contexts affect medical student's reactions or responses when exposed to various educational situations to develop their clinical reasoning ability?

REC ref: 266-1903

Name of Researchers: Dr Anna Richmond, PhD student in medical education. Supervisors: Mr William Atiomo, Dr Simon Gay & Dr Rakesh Patel

Name of Participant:

1. I confirm that I have read and understand the information sheet for the above study which is attached and have had the opportunity to ask questions.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

3. I understand that should I withdraw, more than 7 days after the interview has taken place then the information collected so far cannot be erased and that this information may still be used in the study analysis.

4. I understand that relevant sections of my data collected in the study may be looked at by the research group and by other responsible individuals for monitoring and audit purposes. I give permission for these individuals to have access to these records

and to collect, store, analyse and publish information obtained from my participation in this study. I understand that my personal details will be kept confidential.

5. I understand that the Focus Group/interview will be audio recorded using a digital device and that anonymous direct quotes from the interview may be used in the study reports.

6. I understand that what I say during the Focus Group/interview will be kept confidential unless I reveal something of concern that may put myself or someone else at any risk. It will then be necessary to report this to the appropriate persons.

7. I understand that information about me recorded during the study will be made anonymous before it is stored. It will be uploaded into a secure database on a computer kept in a secure place. Data will be kept for 7 years after the study has ended and then destroyed.

8. **Optional:** I agree that my research data may be stored and used in possible future research during and after 7 years and shared with other researchers including those working outside the University.

9. I agree to take part in the above study.

_____ _____ _____

Name of Participant Date Signature

_____ _____

Name of Person taking consent Date Signature

Appendix 8: Excerpt from reflective diary

F02

This participant was a faculty member and gave insights into what should be happening but seemed resistant to questions that suggested that it might not be working in reality although we did touch upon how infrastructure constraints affected the student's ability to get real life contact with patients in some circumstances (not a CMO I was working on however).

Many questions were answered with other answers, and he seemed to have his own agenda of how things should be taught based upon the way that he teaches and an assumption that all people therefore teach this way.

He said that he encourages NAR, and this is what we should be aiming for, and he would encourage this in students who outwardly appear confident where he is also happy, they have knowledge.

F03

Again, felt like a focussed interview and I was able to ask about both their role as in faculty and as a teacher (GP). Some of the discussion focussed around NAR and AR together and the fact that in a higher knowledge student this was something he encouraged of the students. This participant has a high knowledge base of clinical reasoning principles generally and so this helped the interview progress.

Clinical reasoning development happens from the beginning of the pre-clinical course by laying the foundations, introduced early in the course, very much related to what the patient thinks and presents themselves to the health service. Very much based on allowing the patient to tell you what is going on rather than going with a pre-conceived set of ideas.

Because all of the students are GEM, mostly they have experience to ask why something is the case rather than just accepting so the teaching likes to make use of this (specifically with

respect to teaching that starts with prototypical presentation and then becomes more complex) students have more ability at the outset to understand the fallibility of knowledge but this is not the entire picture. Students are selected to be more inquisitive, so these then form the student population.

There is a longitudinal aspect to teaching clinical reasoning as it compliments many different modules and develops over time

In his own teaching – has longer appointment times to enable teaching to occur as well as ensure the patients' needs are covered and discussion and collaboration with the student. With a shorter time, this is not always possible. So, the context of allowing extra time is required to enable the student to get the best out of the experience. If students are more experienced (normally determined by stage of training – cp2/cp3) they may be allowed to consult on their own and you can tell the ones who have the knowledge as they have a good structure for presenting cases – this is a sort of assessment of the student's ability. No assessment made of self-confidence of the student in this situation and whether this is an appropriate level of confidence.

<u>Reflections ahead of student interviews</u>

The other interviews have highlighted some key contexts, such as preoccupation with exams leading to less interest in reasoning development educational activities even though teachers understand the importance of this. Development of knowledge is key, but I imagine students would have less ability to tell which activities are good for actually building knowledge and which are not (given the nature of not really knowing what is helping and activities that seem harder are better, but the students might not like them).

Students should be able to give good mechanisms on the types of activities that they have had context with, i.e., have you just sat in a clinic, how often, what is going through your mind when you're in this situation. Can you always follow the thought process of the consultant, what helps your understanding in these situations?

They should also be able to say how they feel in simulated and real patient encounters – and why this is so.

It would be interesting to find out how they feel about being asked to go through everything when they already know the answer, does this help them or not? Does it cause frustration at having to explain themselves – if so, is it helpful for learning to explain themselves? Have they ever been asked to trust their 1st impression? How do they react to this and why?

We could also touch on peer-to-peer reasoning and near peer teaching i.e., CTF's

The key things to elicit from the student interviews is the mechanisms – what's happening in inside their heads to make them react in the certain way – asking why might elicit the contexts. Questions like – 'what were you thinking when you were in that situation' may be helpful, also why do you think that was, or more specifically, why did you feel frustrated and then asking what could have been done differently to help may bring out other interventions that are more likely to be successful. Might ask about whether they find it different in different clinical specialities, is this because they have a higher knowledge in certain area? (Trying to think about domain specific knowledge)